TIME / SCHEDULE CONTROL OF ENGINEERING PROJECTS IN THE SOUTH WESTERN CAPE

BY

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I, **Antony John Möller**, submit this thesis in part fulfilment of the degree of Master of Science in Engineering. I claim that this is my original work and that it has not been submitted in this or in a similar form for a degree at any University.

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ABSTRACT

In the evolution of project management as a distinct field of management, there seems to have developed greatly disjointed theory on project control. As a result, the modern practitioner is often faced with contradictory and confusing advice on project time/schedule control requirements. This research integrates and extends present time/schedule control theory. It includes a review of the literature, in which the fragmented theory is pieced together in a model describing the operation of a control system. It uses an industrial survey of engineering projects in the South Western Cape to highlight current time/schedule control trends and to establish the existence and form of relationships between project success, project characteristics and time/schedule control methods. The broad scope of the research has made it possible to set rough guidelines for the practising project manger, in the selection of time/schedule control requirements, and to highlight areas for further research in this area of project management.

SYNOPSIS

Engineers have been involved in project activities probably as long as Engineering has been a profession. However, it is possibly only because of the increasing complexity of recent project activities, and the time consciousness of our modern society, that there has grown an awareness that Project Management is a distinct field of management.

In the growth of this field of management, there appear to have evolved what are often disjointed theories, speculations and inferences on various aspects of project management. For this reason, the modern day project manager, in attempting to control the time/schedule of his project, is faced by several techniques or methods to "solve his problems". Many managers find that the theory available merely compounds their problems and, as such, this research has focused its investigations into the time/schedule control of engineering projects.

The scope of the research has been purposefully wide, in order to meet a number of objectives. The first of these objectives was to bring together the fragmented literature, on those aspects of project management which are related to time/schedule control and to place the practice of such control into perspective in terms of project management as a whole. A second objective was to determine the significance of the various techniques available for the control of project time/schedule. Another objective was to establish what determines the success of the control techniques and the ultimate success of the project. It was also an objective to determine the actual industrial practices of current project managers in such control. Lastly, it was the purpose of the broad based scope to highlight topics for further research in this area of project management.

In order to meet these objectives, the method adopted in the research has been to firstly conduct a literature survey in order to establish the state of the theory on project time/schedule control. Following this an industrial survey questionnaire was sent to engineering and industrial practices of the South Western Cape, late in 1989. The results of this survey were then analysed and evaluated in terms of the literature survey, in order to draw some practical conclusions.

In the literature survey, it was found that although the theory on time/schedule control was fragmented, most references had approached it from one of three perspectives. There were those authors who discussed time/schedule control from a systems view, there were those that considered the control methods as a series of procedures, while there were a few who considered the structural variables associated with the project's make-up and tried to relate these variables to project success and the use of control techniques.

The response to the industrial survey provided a set of 173 "real world" projects for analysis. This analysis consisted of simple graphic devices and more rigorous statistical procedures such as analysis of variance, contingency analysis and log-linear modelling. The simpler graphic and informal trending procedures were used to establish the practices of local industry in the South Western Cape in terms of project characteristics, control techniques used, authority responsible for choice of technique and the success of the project. The more rigorous methods were used to establish the existence and form of relationships between project characteristics, time/schedule control methods used and the ultimate success of the project.

The research found that it was possible to piece together the fragmented theory of time/schedule control, by developing a graphic model which describes the operation of a control system, where this system fits into the management of projects in general and what the purpose of the control techniques are. It was further found that the level of understanding of time/schedule control systems, and the use of techniques, in the South Western Cape, were in general not very advanced. It was possible from the statistical procedures to establish a rough set of guidelines for project managers in industry, which point out some the inferred fallacies of the literature. Such fallacies concerned the one to one relationships between project success and project characteristics, and between project success and the type of control methods used.

It was established that there is significant statistical evidence to suggest that the choice of control methods, to suit specific project characteristics, could influence the ultimate success of the project. However, due to the limitations in the survey procedure and the size of the survey response, it was not possible to conclusively prove this multi-variate relationship, or establish its form. What was clear from the wide scope of the research was that there are several areas for continued research in this area of project management.

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1. INTRODUCTION

Planning, Leading, Motivating, Organising, Controlling and Co-ordinating are the six functions pivotal to management in general and are certainly of no lesser significance to the management of Engineering Projects. Time, as with any other resource, requires the careful application of each of these six management functions in order for a project to come to a successful conclusion.

This research work studies the management of engineering projects, by examining the manner in which this crucial resource (time) is controlled. As a considerable number of Engineers are involved in project work of one form or another, and because of the recent growth in the awareness of Project Management in general, it was felt that research into time/schedule control theory and the application of this theory (specifically to local industry), could be of great significance to those managing engineering projects.

In order to investigate this large topic, the scope of the research has been fairly broad and has, therefore, not been able to cover any of the issues in very great depth. The objectives of the work are firstly to piece together the fragmented literature on such issues as control systems, project structural variables and the use of control techniques. This would be done in order to place the management of the resource time into some perspective within the management of projects in general. The second objective is to identify any functional relationships between such variables as "project success", "Time/schedule control techniques" and "project structural attributes" (ie. characteristics or environment). Thirdly, the research will attempt to highlight current industrial practices in the time/schedule control of projects. Lastly, an objective will be to determine whether there are further areas of research in this field, possibly on issues which will more closely investigate specific aspects of time/schedule control.

If these objectives can be met, this research should provide the practising project manager with some insight into the philosophy of time/schedule control of projects, as well as some guidelines on the application of various techniques and procedures, and the impact which such applications could have on the ultimate success of the project. It should further be of use to the research fraternity, by highlighting further study areas which may lead to a broadening of the understanding of project management in general.

The approach which has been adopted in this research, has firstly been to investigate the theory of time/schedule control of projects in current literature. It has then been to structure the observations and statements of the authors from the literature, into a form which will facilitate piecing the fragmented theory into an understandable whole. Following this, an industrial survey has been undertaken to determine current industrial practices and to establish the validity of the theory which relates project success to; control procedures used and project structural attributes. Lastly, a theory on the philosophy of the project control systems has been proposed, the findings of the industrial survey have been discussed and the literature theory has been compared to the findings of industry. This has been done in an attempt to draw simple conclusions for practising project managers and subsequent researchers.

2. LITERATURE SURVEY

> "Time represents a special asset that must be used efficiently or lost. Very few project managers are careless about accounting for money per se. Yet unproductive uses of time are as wasteful as squandered expenditure. Moreover, it almost always costs more to catch up than it does to work steadily".

Ruskin's quote [35] expresses a widely held sentiment in the literature about the importance of time as a "key resource" in the management of projects. There also seems to be quite general consensus that the control of this resource is as important as the control of cost, through recognised accounting procedures, or quality through "Quality Assurance and Control" (QA & QC). This explains the existance of considerable literature on project control in general and more specifically on time/schedule control.

The theory expressed in this literature appears, however, to be quite fragmented, with opinion divided on certain fundamental issues. What is apparent on reviewing this literature as a whole, is that each of the references has approached the topic from one of three perspectives. These perspectives are interrelated, but very few of the references have dealt with more than one of them and even fewer have tried to relate all three.

The three perspectives from which the references appeared to approach time/schedule control, can be summarised as follows:

i. **Systems View;** References adopting this approach, emphasised the understanding of the position of control (more specifically time / schedule control) within the overall project management system.

ii. **Structural Factors;** Those adopting this approach, stressed the effect of various factors on the level or type of control required and on the ultimate success of the project.

iii. **Methods Approach;** Those adopting this approach, concentrated on the choice of a suitable method to control the project time/schedule from the diverse (often prolific) techniques, algorithms, heuristics, systems and procedures described.

Most authors seem to regard one of these perspectives as being the "essence of project control". From the overall view made available in this thesis, however, no single perspective suffices. As such, all of these facets will be considered during the research, in order to fully understand time/schedule control.

The remainder of this section will be devoted to discussing the three viewpoints. Each will be discussed under a separate sub-heading and, in each case, the predominant suppositions of the authors will be highlighted. This researcher's conclusions will be discussed in a later section of the dissertation.

2.1 SYSTEMS VIEW

The authors who have adopted the systems perspective are those who tackled the project management issues purely from a holistic point of view. They have considered the "WHY" of project management topics in great detail, but the "WHERE" and "HOW" only superficially and in generalities. It is in articles such as that of Sherman [38] and Mc Donough and Kinnunen [20], that the management systems are defined to be different from the actual techniques and methods used in the management of projects, in that these "systems encompass the entire process of establishing and achieving organisational goals".

Might et al [23] argue that even although the recent fixation with network approaches to project management have all but made PERT/CPM synonymous with the concept of project management, the systems view remains vital to understanding the place of such techniques in the overall management of the project. They suggest that mere techniques such as network analysis are formalised planning procedures and provide an insight into the time phasing of the project, but not an understanding of the management systems of the project.

A fairly substantial number of references have considered one or more of the elements of a project management system, such as; planning, control, information systems, organisational theory, productivity etc. Yet very few papers could be found which attempted to tie all these elements together in a total systems overview. Those which were found included an article by Knoll [18] "Project management and control - a consultants approach" and an article by Truman [40] entitled "Development and Implementation of project management systems". Knoll describes the individual elements installed, by a specific consultancy firm, which form the sub-units of a total project management system. The elements, seen in figure 2.1, include; key procedures, reporting mechanisms, the writing of manuals, information flow and management philosophy.

Truman believes that the total project management system has essentially two ingredients, one being an information system and the other being a control system. He sees them as being both mutually related and dependant on each other. As seen in his diagram (figure 2.2), he envisages the information system as providing timely, accurate and structured information on cost, schedule and performance to a control system which produces management decisions and direction.

Although neither figures 2.1 or 2.2 really provide an adequate picture (conflicting in some respects), what they do provide is the key to the place of control in the total project system and the understanding that control is merely one element in the overall management of projects.

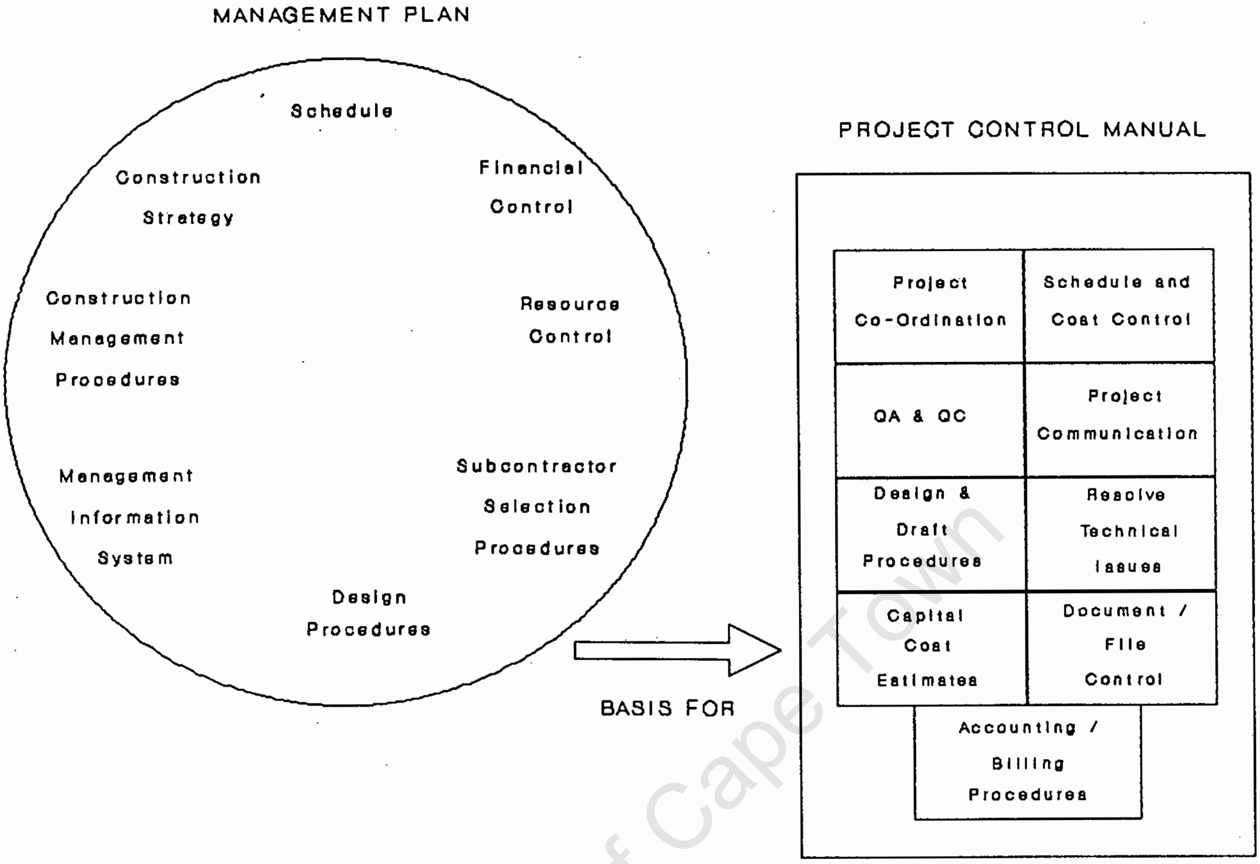


Figure 2.1: Managment and Control - A Consultant's Approach

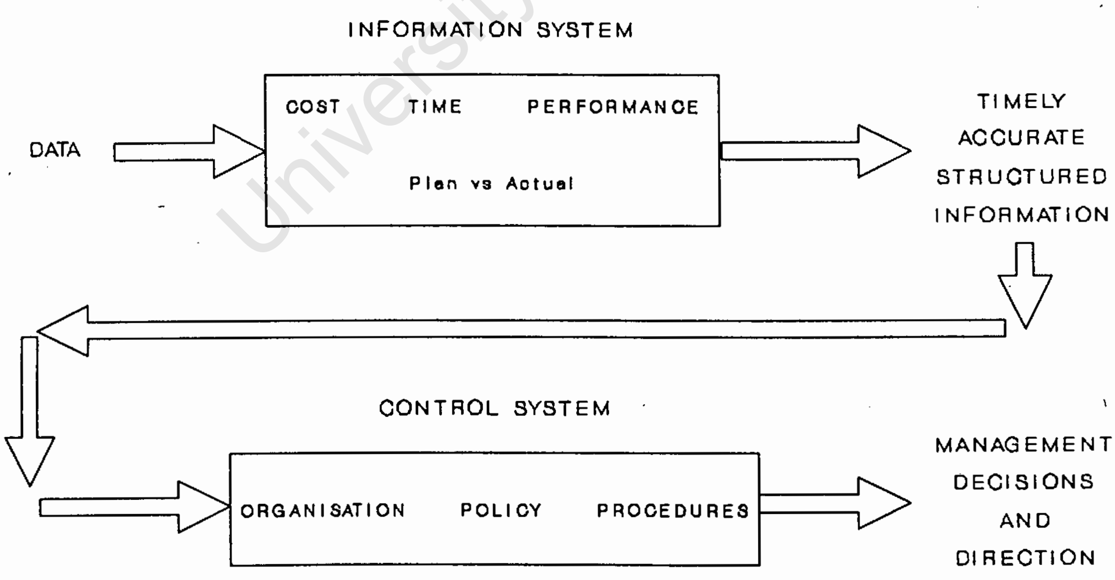


Figure 2.2: Information & Control System

The above diagrams and references suggest that the project management system is made up of a number of sub-systems, one of these being the control system. The emphasis of this research work is, however, on the control system environment. Those references which consider project control systems as opposed to project management systems in general, highlight that the project manager is continually playing off the three facets of control (Time/Schedule control, Cost control, Quality control) against each other. These three facets of control are often in conflict, as Kerzner [16] strongly points out, and it is only with a deep understanding of the environment in which the project finds itself, that a decision on the overriding facet, for a specific problem, can be made. Not only does this research concentrate on the control system but, more specifically, it has concentrated on the time/schedule facet of control.

The references which have considered control systems, tend to view the concept in slightly different ways. For example, Might et al [23][22] researched the use of what they saw as different systems and defined these to be a grouping of techniques which could be either "Detailed task planning/monitoring techniques, Planning techniques, Reviews/Reports and Monitoring techniques".

Mc Donough and Kinnunen [20] observed the elements of a control system to be; Setting goals, Monitoring progress, Management response and Incentives. Kerridge [14] simply listed ten steps that he felt should be implemented to make up a control system. Cusack [6] highlighted the intrinsic relationship between Planning and Control, and their mutual dependance. His article points out that one of the main purposes of planning is to permit control, as control is not possible without a planned baseline against which to evaluate deviations.

Kerzner's book, "Project Management for Executives" [15] concurs with Cusack, but suggests that there is in fact a difference between a "control system" (which includes elements of Planning, Estimating, Scheduling, Reporting, Trending and Forecasting) and the elements of a "control function", which he sees as being a subset of the control system. Truman [40] continues this notion by suggesting that the "control function" is one which; identifies deviations from plan and hence takes corresponding action. This function he sees containing four elements namely; Monitoring of objectives, Reporting, Evaluating and Corrective action.

Essentially, one can see from the above references that there is not general consensus in the literature as to what a "control system" is. What the above references imply, is that the control system is a sub-system of the project management system, that the control system controls essentially three elements (Time, Cost and Quality) and that the control system itself, has three main constituents, namely:

- A planning function
- A monitoring function
- A control function

These functions rely on information and its communication to operate and some authors suggest that all such functions are integrated to some extent. Each of these functions, as well as information communication and the integration of these, have been addressed in the literature from a systems viewpoint in some depth. As such, a brief review has been conducted of each topic making up the a control system, namely; Planning, Monitoring, Controlling, Information and Integrated systems.

2.1.1 Planning

In the past, a distinction has been made between the "planners" and the "do-ers". The former include the individual, or group of individuals, who produce "complicated looking plans, which are not used to manage the project work, and serve only to impress the uninitiated and decorate walls" [10]. The latter are generally regarded as those who are involved in solving the every day practical problems of the real world. From several of the references highlighting the importance of planning, it now appears that this distinction is all but extinct.

The question that remains unanswered, however, is whether the level of planning and the high regard thereof, described in literature, is actually being used across the board in practice, as has been suggested. This is strongly doubted.

The high regard in which this task is held is clear from the references that take the systems view of project planning. Kirschenman [21] suggests that the time spent on planning should not merely be regarded as a line - cost item, the cost of which is to be minimised, but rather as an investment and any associated benefits regarded as a return on investment. Graham et al [9], it appears, agree with this when they comment that sound planning is the "hallmark of a successful project". Paulson [28], using an analogy of travelling in a car with windows blacked out, attempts to explain how crucial the proper execution of this task is.

The question now arises as to what makes this exercise so important. Here, however, the references provide no one single answer. Most references, such as Kerridge [14], Paulson [28] and Mc Donough et al [20], recognise that planning is the "baseline for control" and without this baseline, the project will inevitably take longer and cost more than would otherwise have been the case. Some references, such as Milligan [24] and Larson et al [19], recognise that there is also an element of pre-planning in which it is required to plan such things as contracting strategy, organisational requirements, co-ordination procedures, execution strategy and engineering scope. As Larsen and Gobeli put it; "Projects with clearly defined objectives to begin with, have a clear advantage over those in which objectives are vague or undergo constant revision."

Harrison [10] took this one step further, when he defined the above two elements of planning (namely pre-planning and task planning) to be "Launch Planning". Here he saw the project scope, goals, objectives and strategy being laid out, and the base-lines for the control of time cost and quality defined. He then recognised that planning is not a one-off activity to be conducted before project commencement, after which it would be possible to "pin it to a wall and stand back pleased with oneself". He pointed out that planning should be seen in terms of a continuous control cycle and hence defined a secondary stage of planning to be "Control Planning". It is in this stage that he saw plans continually being reconsidered and updated in the light of occurrences through the life cycle of the project.

2.1.2 Monitoring

"Project monitoring is neither a neutral nor necessarily a benign activity. It is an intrusion in the work of the organisation that can be instrumental in changing the course of the project" [25]. In this quote Morton alludes to what the literature in general regards the monitoring function to be. Firstly, it concurs with Kerzner [15], Paulson [28] and Pinto et al [29], by pointing out that monitoring in itself is not a project operational task, as it is this function which tracks operational progress in comparison to plans. Secondly, what Morton attempts to point out, is that although this function is regarded as an "intrusion" on the project work, by attempting to collect meaningful information, it is this information which is used by the control system and could thereby be instrumental in changing the course of the project.

There are two further references worth mentioning, which have considered the systems view of project management. Bent [3] saw the monitoring function as being synonymous with the scheduling of the project. This is seen as being a major misconception, in that the schedule is a tool which is monitored in order to communicate information to the project manager for action. It does not in itself constitute the monitoring function. Harrison [10] more appropriately viewed the monitoring function as being one which supplies information to the project manager, in order to "show progress, highlight problems and bring deviations (from schedule) quickly to his attention".

2.1.3 Control

The author who possibly best summarises the place of the control function within the control system is Kerridge [14], when he states; "No control system works unless adequate time is spent up front in planning the work, and thereafter, properly monitoring and controlling against the plan." Indeed, references such as Cohenca et al [5], Cusack [6], Milligan [24] and Ruskin [35], agree that the control function is separate from the monitoring function, in that the project manager should use the information generated from monitoring actual project performance, as a tool to make control decisions and not merely as "a pro-forma exercise to meet someone else's requirements". These control decisions, on the corrective measures to be taken, should be made after evaluating the information and after identifying discrepancies between planned and actual performance.

Schenk [36] suggested that the most important element of project control, is the control of changes to the plan (time / schedule and other). In this paper, entitled "Configuration management applied to engineering projects", he recommends a rather bureaucratic system consisting essentially of what he calls "configuration control boards", to assess changes in pre-specified baselines.

Bent [4], on the other hand, suggests that the key to effective control is in using the information obtained from the monitoring function and so evaluating schedule, work status and performance. In so doing, he sees it as being important to establish "the scope of the work ahead" and in the light of the new scope, making proper decisions regarding project changes.

Despite the apparent importance of the control function, Harrison [10] points out that very few publications and considerably few training courses exist for project control. He feels that training in control has up until now been "left to accountants, and in the few industries who use them, cost engineers." According to Bent [3] this is wrong, as he feels that "project managers who relegate the control function to a reporting or accounting function are derelict in their duties."

2.1.4 Information / Communication

> "A good decision is a logical one ... based upon the uncertainties, values & preferences of the decision maker. A good outcome is one that is profitable or otherwise highly valued ..., we find no better alternative in the pursuit of good outcomes than to make good decisions, and there is no surer way of making good decisions than to ensure that such decisions are judiciously informed" [6]

It is beyond the scope of this thesis to consider all the procedures and methods involved in gathering requisite data for a project, and to consider the communication requirements for the data in providing useful information. All that this research will attempt to point out, is how information, and information communication, are used in the management of a project.

Those texts which evidence work on control as well as information / communications, include Paulson [28], Kerzner [15] and Graham [9]. Here, information processing and the communication of this information, are not only regarded as the link between the planning and control functions, but also as the "cornerstone" of the control loop and the "lifeblood" of effective decision making.

Might et al [22,23], Knoll [18] and Bent [3,4] mention the requirement to set up communication channels and information systems for the project's specific requirements, during its planning. Morton [25] asserts that effective control is more dependant on the directing and maintenance of these information systems (both formal and informal), than on anything else. As such, he feels that the project manager requires a deep understanding of the "human dynamics" of the project environment. Hribur [11], Roberts [33] and Graham et al [9] discuss the place of computerised databases in the information system. Tuman [40], suggests that traditional company information systems are of little use in a project environment, as they are geared to provide information to functional departments such as accounting.

2.1.5 An Integrated Control System

The Oxford dictionary defines the verb 'integrate' to be the "combining of parts into a whole", or to "complete an important thing by the addition of parts". In much the same sense, authors such as Bent [3] and Harrison [10] suggest that after the project is launched, the function of planning, monitoring and controlling should be integrated into a closed loop, so forming the control cycle or system. Hence they see this control system as one integrated managerial function.

Some authors such as Kerridge [14], Harrison [10] and Knoll [18], have taken this a single step further by suggesting that the integrated control system should unify both time and cost control. Kerridge and Harrison suggest doing this with the "earned value" concept, while Knoll suggested the use of a single document (Project Control Manual).

Very few authors have been so bold as to suggest that all project efforts should be fully integrated. In fact authors such as Paulson [28] and Morton [25] caution against this, particularly through a network approach. They suggest that during the management of a project there exist a series of subsystems, which should not be integrated into one single complex system, but rather remain as a set of independent yet interrelated modules. It is their opinion that although the individual subsystems (such as the time / schedule control loop) are themselves integrated, it would not be possible to fully integrate all of the diverse functions of a project manager (ie. activity and resource scheduling, cost engineering, materials procurement and tracking, QA and QC, etc.). This is because the shear volume of data required would be difficult to collect and would almost certainly dominate and obscure the vital management information.

2.2 PROJECT STRUCTURAL FACTORS

The second project control perspective which authors have used, is to view the influence which various "strategic" factors have on the control of the project, as well as on the ultimate success of the project. These factors they have rather loosely called structural, situational or environmental factors, while citing variables which could be described as being either; those strategic factors which determine the type of <u>environment</u> in which the project finds itself, or as those factors which describe the <u>characteristics</u> of the project.

The distinction between project characteristics and project environment is an important one (particularly to this research) yet it appears to have been totally neglected in the literature. The difference between those variables which are characteristic in nature and those that are environmental, is that variables such project type, size, duration and complexity are independent of the project manager's influence and hence determine the initial characteristics of the project. While variables such as organisational structure, project manager authority, management support, clarity of goals and definition of communication channels (amongst others), determine the environment in which a project, having certain characteristics, will operate.

As the literature has all but ignored this distinction, these two types of variables will jointly be described as structural variables in the text which follows in this section.

In researching the literature which considers strategic project management elements, it was found that various authors attempt to relate these elements in different ways. There are those in literature who have either directly stated, or indirectly inferred, that there is a relationship between structural variables and the type of project controls used. There are those who have attempted to define relationships between the controls used and the level of success attained in the execution of the project, while some have tried to relate structural variables of the project to success attained. Finally, there are a very small number of authors who have attempted to tie all of these strategic elements together by hypothesizing that structural variables determine control requirements, which in turn determine success. As such, each of these functional relationships will be discussed in greater detail in the four sub-sections which follow.

2.2.1 Structural Variables and Control Techniques

As Might and Fischer [23] point out, literature has paid little attention to the way in which specific structural variables affect the appropriateness of various strategic management tools. A vast number of authors, however, tend to inadvertently suggest relationships between some or other structural variable and the type of control techniques employed. An example of this would be Harrison [10] who suggests; "Just as it depends on the size and complexity of a calculation, whether a manager would use a calculator, spreadsheet or a computer model, so size and complexity of the project should determine which technique or techniques he should use to plan"...or control. This suggests that the literature in general feels that some relationship does exist, yet it remains unclear as to what the relationship is and indeed, which variables are most important to the relationship.

The authors who attempt to define a relationship between specific structural variables and the type of control used in a project, include: Cohenca et al [45], who suggest from their research that environmental uncertainty has a major impact on planning time, control time and revision intervals in construction projects. In [41], Veranth emphasises the different schedule requirements for different types of industry and project. Numerous authors either imply or directly hypothesise the relationship between control procedures and project type and size. These authors include Veranth [41], Hribar et al [11], Paulson [28], James & Griffiths [12], Milligan [24], Oxley & Salter [27], Kerzner [15] and Bent [3][4]. Other structural variables said to be of importance to this relationship include; management support, communication channels and management response (Schmidt [37]), clarity of goals, project manager leadership (Mc Donough and Kinnunen [20]) and project phase (Schenk [36]).

It thus appears that many authors suggest that the type of control techniques used should be determined by the structural attributes of the project. Only a few of these authors have tried to prove such a relationship and none are sure what the relationship actually is.

2.2.2 Project Success and The Control Methods

All of the authors who discuss control systems or techniques, imply that the ultimate success of a project is influenced to some degree by the application of the relevant degree of control. The significance of this hypothesis is that those authors who suggest this relationship, are in fact suggesting that its detailed definition ensures a successful project.

Schmidt [37] implies this relationship exists, when he suggests that "schedule goals are more often met when managers use both formal and informal monitoring (and control) mechanisms." Paulson [28] suggests that financial success of the project can be accomplished with correct / improved planning and control of Engineering projects. In a paper entitled "Critical factors in successful project implementation" [29], Pinto and Slevin arrive at ten points which they regard as being pivotal to the successful implementation of a project. Of these factors it is interesting to note that four are directly related to the control of the project (Namely: Schedule / Plan, Monitoring and Feedback, Communication, and Trouble shooting). The authors mentioned by Pinto & Slevin in support of their critical factors all regard the provision for, or the setting up of, control mechanisms as vital to the success of a project.

2.2.3 Project Success and Structural Factors

There are a considerable number of references in which the authors have cited the structural dimensions of the project to have the greatest bearing on its success rather than the control techniques used. These authors suggest that the success of a project is determined by the more static make-up of the project, or even the very characteristics of the project, rather than the more dynamic control systems of the project.

They include: James and Griffiths [12], who feel that the key to the success of small projects lies in the utilisation of a very experienced project team and Milligan [24], who highlights the relation between success and the competence of functional managers and the attitude of the project manager to group participation. Schmidt [37] sees the support given by management to the project, and communication channels set up, as being of vital importance to success. Baker, Murphy and Fisher (referred to in Pinto & Slevin [29]) suggest such variables as clarity of goals, adequate funding, team capabilities, absence of bureaucracy and goal commitment are all important to success. While Morton [25] adds to this list by suggesting such variables as organisational philosophy, the allocation of resources in the organisation and delegation of authority. In the Project Implementation Profile mentioned earlier (Pinto and Slevin [29]), project control related variables are not the only ones suggested to be related to success. The authors also suggest that most of the factors listed above also bear relevance to project success. They further include "responsiveness to clients" as another variable.

It is thus evident from the above references that there is some theoretical support for the idea that the structural dimensions of a project can influence project success. The problem is, however, that there is no practical research to conclusively prove the relationship, nor is there consensus on which structural variables effect success and how the success is effected.

2.2.4 Project Success, Control Methods and Structural Factors

Until now the above discussion has highlighted the insight which literature has provided on the one-to-one relationships between various variables, i.e.: Between control systems and structural variables, between project success and control systems, between project success and structural variables. Yet extremely little could be found which addressed the joint relationship between project success, control systems and structural variables.

The first work which attempted to tie these relationships together, has been described in a paper written by J.K. Pinto and D.P. Slevin [29]. These authors used an extensive literature survey to identify what they felt were the "critical factors in successful project implementation". In so doing they provided more of an insight than an analysis, into how they felt the success of a project could be influenced by the use of an implementation profile, consisting of both structural variables and control system elements. However, their article concludes that the authors remain "at a loss as to how these factors should be considered".

The other piece of work which attempted to join these elements into a single cohesive relationship, was that of R.J. Might and W.A Fisher [22][23]. In their research, what they attempted to do was to determine what they called the "structured dimensions" of project management, which need to be addressed before selecting the specific control system applicable to the project. This they suggest would determine the success of the project. They essentially did this by testing the null hypothesis, that:

> "The relationship between critical situational conditions and the level of implementation of control systems, do not affect the level of success of development projects."

Interestingly, the factors they regarded as being "situational conditions" were such things as project management administration capabilities, project team's enthusiasm and support and the communication within the division. These factors could not really be regarded as project characteristics, but more as the project's environment. Ultimately, their research showed that project managers should consider the environment in which they are working when they choose a control system, if they wish to be successful, because no single set of decision criteria could be determined to aid them in this choice.

2.3 METHODS APPROACH

The third perspective which authors have taken in the literature, is to consider the actual methods or procedures used to control time schedule. Whereas the previous two sections (Systems View and Structural Factors) dealt with the "WHY", the "WHEN and the "WHAT" of time/schedule control of engineering projects, this section will consider the "HOW". As such, the view taken here could be described as a micro view of the systems previously described on a macro scale.

Some of the techniques commonly used in control systems on projects will be mentioned in this section, as well as some of those which are less well known. Further mention will be made of the references to the use of computers, the use of a planning engineer or planning department and the relative success attained with the use of the techniques.

This section discusses the literature view of the management tools at the disposal of the project manager and presupposes that the distinction between control techniques and the "control systems" themselves, which may be made up of different techniques, is clearly understood.

2.3.1 Control Techniques

It is important to understand that those procedures hailed as being "control" techniques in literature, are in the strictest sense of the word not controlling in nature. They are more often "planning" or "monitoring" related, as the control itself is merely a corrective or feedback action applied to the course of the project, as described in the Systems View (2.1). As such, the term "control technique" will in this section be used loosely to describe the procedures used in the control system, which enable the control decisions to judiciously be made.

Although it is not within the scope of this dissertation to list and critically appraise all such techniques, a few of the more well known, and some of the more obscure techniques, will be discussed for the sake of completeness.

a. Standard Graphic Techniques

The first group of techniques, namely **Bar / Gantt charts**, **Milestone charts** and **Line of Balance** are, it appears, widely hailed as being techniques which are easy to use in the planning stage of the project. They are capable of providing visible evidence of actual progress against planned schedule. As Milligan [24], Kerzner[15] and Harrison [10] state, the success of these techniques is due to the fact that their meaning is clear and simple to understand for anyone used to reading an elementary graph. These references point out that in projects which are complex and very large, and where frequent revision may be required, these techniques only have limited applicability. Indeed, Hribar and Ashbury [11] went so far as to state that the bar chart / milestone method "is not suitable for actual schedule maintenance and the control of design and construction activities" because of its simplicity.

Further limitations referred to in these methods, include:

- Their unsuitability for linking to cost or resource control.
- Their limitation of reliability to areas where estimates of duration can be made.
- Their inability to forecast trouble (as they are historic in nature).

b. Network Methods

The second, and most mentioned set of techniques are those known as Network Analysis (which include Precedence diagrams, PERT, CPM and Arrow Diagrams).

These techniques were developed in the late fifties and began to grow in popularity in the sixties and the early seventies. This was chiefly due to the fact that these methods effectively handle the interrelationships between activities on complex projects. They identify those activities of criticality to project duration and when used on computer, they permit integration with the project information system.

As Harrison [10] points out, in the seventies there was a strong association between the use of these techniques and the size of the project involved. On larger projects, their "use became accepted as typifying good practice". As such, they became used as a major sales factor when bidding for contracts.

In the late seventies and early eighties, however, the value of network analysis came under close scrutiny. Indeed, Morton [25] points to several references from the late seventies and early eighties which suggest that decision making is not only a function of rational choices. For this reason the construction industry felt that these techniques were inadequate and hence felt that a return to the earlier Line of Balance technique should be made. He further points to research at this time, which suggests that time and resource are not interchangeable and that it may sometimes be more effective not to stress the critical path. Wager [42] supports this argument when he suggested that at about this time, these techniques began to decline in popularity because it was felt that they were "cumbersome, inflexible and took too long to process into meaningful results.

Since the early eighties these process oriented techniques have, however, become more accessible to the project manager because of the dawn of the computer age. This is confirmed by Reiss [30]. In this regard, computer applications are one set of tools in many, which are available to the project manager. This is contrary to the understanding put forward by many authors and lecturers, who regard PERT/CPM as synonymous with project management.

As Morton [25] states; "There is a wide gap between the mechanics of network analysis and the realities of an organic world of constantly changing relationships". Although these techniques attempt to apply a mathematical rigor to a dynamic set of circumstances, authors such as

Milligan [24] and Cusack [6] caution that in ones enthusiasm for developing networks and computed processing of numerical detail, one should take care to use "what is sufficient for a project and avoid using systems which are too elaborate to be effective".

c. Non-rigorous Methods

Those techniques which do not have strict mathematical procedures for controlling project schedule will be classified as the non-rigorous methods. These include such things as formal and informal meetings, as well as the many forms of written reporting, including detailed written reporting, formal proforma completion and informal "report-backs", as well as a variety of descriptive graphics.

The literature within the field of specifically project management does not pay very great attention to this group of techniques. It would appear that most project management authors tend to regard these as standard management procedures, which are covered in general management literature and as such, tend to summarily dismiss them.

There are, however, some authors such as Cusack [6] who point out that "it is acceptable to sacrifice strict mathematical rigor in favour of operational acceptability". Indeed Kerzner, in at least three books (namely [15][16] and particularly [17]), tries to highlight the fact that procedures such as "First Hand Observation, Oral and Written reports, Technical Interchange Meetings", are vital in making information available for project evaluation (be it cost, technical, or schedule information). Milligan [24] points out the importance of such procedures in monitoring project progress against plans. He particularly discusses the place of standard progress forms, "Management by

Exception" and how the regularity and frequency of formal meetings can affect the effectiveness of such control.

McDonough and Kinnunen [20] try to identify the management control systems that have been used to control development projects. According to their discoveries, written reports have helped to keep projects headed in the right direction, by forcing the project leaders to show where they have been and where they are going. It also appears that "Management by Walking Around" is a key method to successfully controlling these projects.

The suggestion that such non-rigorous methods as Schedule Design Reviews, Periodic Management Reviews and Periodic Technical/Cost/Schedule reports, affect project success has been pursued in a survey conducted by Might and Fischer in 1984 [22][23]. The research suggests that project size could influence the success of such techniques, but concludes that there is considerable room for further investigation.

The "cornerstone" of the descriptive methods is, in literature, undoubtedly the Work Breakdown Structure (WBS). As Kerzner [15] says, "whenever work is structured, understood, easily identifiable and within the capabilities of individuals, there will almost always exist a high degree of confidence that the objectives can be reached". It is almost certainly on the basis of a clear WBS that descriptive techniques such as progress "S" curves (Detailed in Bent [4] and Paulson [28]), productivity indices and learning curve estimates, become meaningful. For without a WBS which defines all the efforts to be expended, which allows assignment of responsibility and which permits the setting up of schedules to accomplish the work, literature suggests that there <u>is</u> no basis for control.

d. **Obscure Techniques**

Literature seems to abound with heuristics, methods, procedures and techniques, which claim to be; "a simple way to estimate time required", "a diagnostic in accessing project status", "a disciplined means for reducing overruns", "a simple approach to control of project duration" and "an aid to keep focus on project goals". Despite these claims, they are seldom simple and rarely applicable to more than a few situations.

An example of such a "simple approach" is given in a paper by Cusack [6], in which he presents a heuristic approach to the planning and control of project duration and cost. The heuristic works on the intrinsic relationship between cost and time, by using the precedence network to define task logic and a critical path. It then alters critical activity durations (with associated cost changes) until the critical path has a minimum cost and duration. After this, all non-critical-path activities are altered, until they are at minimum cost. The heuristic thus provides an "optimal" project schedule.

Another technique based on the information obtained from PERT, is that of Schmidt [37]. The technique, in fact, is built from PERT information, in that it compares actual time used on a project, against the percentage completion of the critical path. As with progress "S" curves, or a manufacturing process control chart, the actual project progress is graphed against a planned performance standard. Schmidt suggests that this method not only monitors and reports on this progress, but also "controls" the project. This is not really true, as the technique merely sets control lines, which provide a warning of possible schedule overruns.

Where the above authors have attempted non-rigorous mathematical solutions to schedule control problems, several other authors have considered logic or procedural approaches. Authors such as the Engineers at Deere & Co. [7] suggest that a simple control method is to draw up a logic chart, which highlights and time-phases major milestones of the project, showing the prerequisites to each milestone. They believe that the action of significant schedule control can only come about as a result of the effective communication of project schedule objectives and progress. As such, they regard this technique as being a very simple, yet effective, communication tool.

Similar approaches have been considered by such people as Schenk [36] and Pinto et al [29]. The former suggests an empirical model of the project implementation process, consisting of a series of critical project factors to be considered. The project manager is then presented with a sequential checklist, or set of milestones, that enable him to track the project through each stage of its implementation process. This enables the manager to determine where the project is, in terms of its life cycle. The latter reference suggests a control method which is merely a disciplined means of curbing overruns caused by engineering changes.

As can be seen from the brief summary of <u>some</u> of the techniques used in the control of project time/schedule, there are indeed a great variety of techniques that can be used. The literature does not prescribe one of these to be the single "elixir for all ills". It would be more appropriate to say that, although many authors praise certain methods, these praises are seldom as bold as to state total applicability. In most cases the range of applicability is qualified, to encompass certain project structural attributes (ie. Project phase, industrial sector, age, complexity, or duration).

Morton [25] summarises this sentiment, by stating that Project Managers should consciously think about the techniques or procedures they use. He feels that rigid adherence to prescribed procedures, or sophisticated methodologies, can easily stifle flexible and creative management. Morton argues not for the abandonment of such mathematical techniques as network analysis, but for a more deliberate evaluation of their application and contribution. Too often, he believes, the "methodology has become a substitute for a deep understanding of the project".

The Project Manager remains responsible for project outcome and literature tends to suggest, that if he wants to meet time schedules (as well as budget schedules), he should be realistic about the time spent on planning and control techniques. If he is not, he is likely to get the level of control he is willing to tolerate.

2.3.2 Computer Applications

Literature at present seems to abound with discussions on the latest software systems, to aid the Project Manager with the planning and control of projects. It is not only the computing literature that now carries the claims of the "ideal" system to "take the load off the Project Manager". More recently, even those industries such as Construction, General Engineering and Marketing, which have been traditionally conservative in their management styles, that are showing evidence of moving in the direction of computerised management processing.

It would seem that some authors are so bold as to consider the choice of a computer package synonymous with the choice of a management system. For example, Reiss [31], in an article entitled; "Choosing a project management system", evaluates a range of micro-computer package options. While Wager [42], in an article entitled "Why don't contractors manage their projects?", tries to discover why it is that so few construction contractors use project management software.

When considering the broad spectrum of literature on computers in project management, the general areas in which most authors tend to fall when discussing their application to the control of project schedule, are;

- Their use as a tool to manage, store and manipulate large amounts of data (Data Base Management Systems) and hence produce control information. (Morton [25], Pinto [29])
- Their application for fast numerical processing, associated with such techniques as network analysis. (Cusack [6], Oxley [27], Sherman [38])
- Their ability to produce neat and accurate graphics from data, in order to communicate control information. (Reiss[30,31], Robison [34], Wager [42])
- Their potential for future developments in such areas as Artificial Intelligence (AI) systems, and the related so-called expert systems, for decision making on a wide range of management control problems. (Reiss [30], Tuman [40])

Not all authors praise the merits of intricate programs and massive data bases, and the large networks or reams of printouts they may produce. There are those, such as Graham et al [9], who prefer to suggest that computers merely compute, while it is the Project Manager who manages. They suggest that such things as integrated computer databases, can only facilitate the Project

Managers ability to manage and cannot replace it. The inference is that the computer system "cannot provide the necessary judgements upon which to plan and direct future actions. Nor can the computer generate the required commitment to pursue a specific course of action". Such actions remain the responsibility of the Project Manager himself.

Morton [25] strongly supports these assertions, when he suggests that network packages appear to be a god-send to people like the inexperienced planner and the risk averse Project Manager. He suggests that to such people, these computer based packages, with their massive networks and volumnous printouts, offer welcome shelter from the human dynamics of the project. But, he warns that although computers provide the ability to manipulate more data and process ever larger networks at greater speeds, one should still remain cautious. Unfortunately, the larger the network (or the data base), the harder it becomes to collect all the necessary progress information to update the network and the more complicated it is to change. As such, he recommends that the Project Manager can avoid thoughtlessly using such alluring techniques by always considering <u>what</u> is needed before deciding <u>how</u> he will meet that need.

It would seem that there is an abundance of computer software available on the market at present, and considerable advanced computer hardware, which is capable of assisting the manager not only in planning the project, but also in his control of project time against these plans. It seems that some authors feel that the use of computers in the control of project time, through scheduling practices as well as informed decision making, are the way of the future and the most obvious direction in which a manager should look when setting up a control system.

There are, however, those authors who believe that those who make use of computer based control methods (be they network packages, data base, or simply scheduling procedures), should remember that the computer is merely one tool at the disposal of the Project Manager and that the use of this has no more intrinsic relation to project success, than any other manual technique. As such, one should avoid the human inclination to equate the use of more sophisticated tools with better project control.

2.3.3 Planning Engineers / Planning Departments

Fundamental to the "HOW" of time/schedule control of projects are not only the evaluation and choice of techniques and tools, for performing this function, equally important is the decision on the people to use these tools. That is, whether the planning, which should inevitably be the basis for the control, should be left up to the project manager and the participants of the project, or whether a centralised planning section should be involved to some extent.

It appears that most literature holds consensus on the fact that it is the Project Manager's responsibility to study the needs of the project as a whole and as such it remains his task to personally coordinate and supervise the formulation of plans. These plans should not only be meaningful to those who execute them, but should also provide the necessary basis for the control of such plans. What does, however, seem to be a contentious issue is the level and type of assistance that should be provided by either a specialist planner (seconded to the project) or by a dedicated planning department.

There are those authors such as Kerridge [13] who rigidly lay down a prescribed procedure for "Organising a Project", in which it is assumed that the Project Manager would assemble a project team. Included in this team he sees a dedicated project scheduler, whose function it would be to assist in the development of the time schedules of the execution plan. Oxley and Salter [27], on the other hand, qualify the use of a dedicated planner or planning department. In their article, which describes a computer planning/controlling system, their motivation for the use of such a system stems from the fact that multi-project scheduling in small firms is a very time consuming job, which when carried out manually would require a "full-time planner". As he states, there are few small firms who could afford such commitment, as such he suggests that such small firms should rather consider the use of computer techniques.

People such as Milligan [24] and Bent [3], point out that the sole use of a specialist planning section for the project would have the advantages that; it would be capable of coordinating the planning with that of other projects, it would be independent of other commitments and it would cultivate expertise in the techniques for planning and control. They do, however, further suggest that there are problems with plans produced by a specialist department or person. As such, there is a fear that these plans could be regarded as the "planners plans" and hence summarily disregarded. There is also the real danger that the up front planning will be left to the planner on his own, while the Project Manager attends to "more pressing issues". In such a case the planner is unlikely to get adequate support from functional managers, so leading to ineffectual plans, with inadequate recognition of the human factors involved in the project, and hence producing an unrealistic model against which to control.

Harrison [10] suggests that it is essential to the success of the planning, that it not be left entirely up to a separate planner or planning department. He feels that the function of the staff planner is merely to assist the Project Manager, by helping him to express his and his project participant's thoughts in the most appropriate manner.

3. RESEARCH METHOD

From the material uncovered during the literature survey, the scope of this research work was developed so as to complement research already covered. The literature survey pointed to several theories and inferences regarding project management systems, project success, project structural attributes, project control techniques and their interrelationship. Few of these theories or inferences had any research backing and, as such, this research will attempt to provide some practical evidence to either support or refute the literature findings.

The method used to obtain practical backing for the literature findings was decided to be an industrial survey. The problem was, however, that the scope of the literature was extremely wide and it would be difficult to cover all the control aspects of the literature within a single survey. It was therefore decided to investigate the structural factors and the methods approach in greater detail, but to leave the Systems View as a theoretical backing.

With this in mind, the second part of the research will determine what schedule control techniques are actually used in practice, and whether there exists some relationship between the schedule control techniques used, project characteristics and project success.

This section of the dissertation has been divided into two sub-sections. The first describes in some depth the procedures adopted in the industrial survey (Questionnaire Construction), while the second details the procedures that were used to analyse the data that was obtained from the survey (Data Analysis).

3.1 QUESTIONNAIRE CONSTRUCTION

In order to determine the industrial practices, it was decided to construct a questionnaire which would be sent to a select set of respondents from local industry. As one of the primary concerns of this thesis is that it should be of use to the engineering manager, it was decided to target the questionnaire at engineering/industrial projects. A further concern was that, for the sake of practical evaluation, the geographical area of the survey should be limited. Hence it was decided to limit the distribution of the survey to the South Western Cape, even though its contents would be nationally, or even internationally, relevant (should further investigation be warranted). The use of the Western Cape as a distribution area had the added advantage that its proximity to the researcher made it easier to conduct follow-up interviews.

Respondents to the survey would be asked to report on practices adopted in specific projects and not on generally accepted corporate practices. As such, it would be important to ensure that respondents remained as accurate in their recording of responses as possible. For this purpose, it was suggested to respondents that they should have knowledge of the procedures adopted for the planning and control of projects, and of the outcome of these projects. It was further suggested that these projects should have been conducted within the last 10 years, not only to ensure accuracy of response, but also to limit the effects which rapid developments have had on the management of projects in recent years. This, it was hoped, would keep the study both current and relevant to today's project managers.

The questionnaire was not only to take account of these factors, but was to further:

a. Be structured so as to easily facilitate the required data analysis.
b. Integrate questions from a second researcher who was studying the methods of project appraisal.
c. Attempt to obtain information on as many projects as possible from <u>each</u> respondent.
d. Determine from the respondents; their name, the name of their organisation and their telephone number. This would make it possible to contact them at a later date, should they be willing and should some of their responses require clarification.

Furthermore, the general rules for questionnaire construction suggested by Alreck and Settle [1] and Moser [26], were to be adhered to as far as possible. These references laid out guidelines for; language usage, question style, the ordering and layout of the questions, scaling factors that could be used, the general structure of the questionnaire in order to ensure a reasonable number of returns to the survey and as accurate completion of the questions as possible.

The questions themselves would be dependent on the specific information required from the respondents. While the way in which these questions were to be asked, and the scaling factors to be applied to them, would depend on the statistical analysis to be performed on the response data.

The questionnaire which was finally constructed and sent out on survey has been included in Appendix A together with the covering letter. It is important to note that the questionnaire shown in this appendix integrates questions for the second researcher, as there was some overlap in data requirements for research data of the two separate theses. The following sections were incorporated in the questionnaire:

3.1.1 Project Characteristics

This was the first section of the questionnaire and was included to establish such project characteristics as:

- **AGE:** This was used to determine how long ago the project was conducted.
- **TYPE:** It would be of importance to know how the respondent classified the project type (ie. as research, development, construction, general engineering ... etc.).
- **VALUE:** Here the respondent was asked to estimate the approximate monetary value of the project, in an attempt to determine the scale of the project.
- **DURATION:** The last question of this section determined the approximate duration of the project.

It is important to note that a distinction has been drawn between what several authors in literature called "environmental variables" and these project characteristics (as discussed in the Literature Survey of section 2.). In this research it was only the intention to determine the effect which Project Characteristics would have on success and not the effect of numerous possible environmental variables on success.

3.1.2 Schedule Control Techniques

The purpose of this section of the questionnaire was to establish not only the types of schedule control techniques that the respondents used on each project, but also who had determined which techniques would be used and why these techniques had been chosen.

It was also the intention of this section of the questionnaire to solicit the opinions of the respondents on a number of unrelated topics in order to get a "feeling" for the projects and people who had worked on these projects. These issues included such issues as relative complexity of techniques, their usefulness and their method of application.

3.1.3 Project Appraisal Techniques

This section of the questionnaire had no relevance to this research work. The reason it had been included is because it was of relevance to a second researcher who had been part of the survey, as <u>his</u> requirements from a survey had overlapped to some degree.

3.1.4 Project Performance

It was of vital importance to establish the respondents opinion on the "success" of each project. It is first of all important to realise that this section is highly subjective and likely to contain considerable bias. Furthermore, there can be several measures of project success. Just as it is important to manage the three facets of a project, namely Time, Cost and Quality, so the success of a project can be gauged by these selfsame facets. For this reason, respondents were asked to estimate the Budget, Schedule and Technical Success of each of the projects.

3.2 DATA ANALYSIS

The data for the research was comprised of the information gathered from the industrial survey. This included both the information from the returned questionnaires and that from the follow-up discussions with a selection of respondents who were willing to provide their name and telephone number on the returned questionnaire. This data was collated into a database of individual projects, with the fields of this database consisting of the question categories on the questionnaire. It is important to note that the follow-up interviews were held on an informal basis and that they were aimed at clarifying the questionnaires where problems were encountered and not at extracting additional information from the respondents.

The analysis of this data took two routes, the first being a **summary statistic and informal trend analysis** and the second being a **formal statistical analysis.**

3.2.1 Summary Statistics

The purpose of this analysis was to roughly analyse the broad data set in order to:

a. Determine the scope and extent of the data attained.
b. Determine the completeness of the data set.
c. Gain an overview of the completeness and validity of the responses to individual questions.

d. Suggest possible flaws in the type of responses attained and hence avoid pitfalls when drawing conclusions during later analysis.
e. Suggest possible simple trends in responses between classes of questions.

In order to meet the above objectives, the data was classified into the four broad categories as set out in the questionnaire itself. These categories were:

A. General project information (ie. project characteristics)
B. Project planning and control
C. Project appraisal
D. Project performance

For the scope of this thesis, only categories (a), (b), and (d) were considered, as category (c) was of relevance to the other researcher. For this reason, all "project appraisal" data was removed from the database.

The first step in the analysis was to verify the data obtained. This was done by assembling the responses onto a single spreadsheet and checking for missing values or possible erroneous entries. At this stage, it became evident that the individual projects could be classified into a number of types, according to response. They are:

a. Those projects which were completed in their entirety. (ie. Where it was evident that the respondents understood the questions and as such provided unambiguous answers.)
b. Those projects where responses were completed to only certain of the questions, either because the respondent felt that parts of the questionnaire were not relevant, or because they ran out of interest.
c. Those projects where responses showed that the respondent had clearly misunderstood most of the questions. In these responses, ambiguities existed between answers to related questions, or crucial questions had been omitted during the answering.

Those projects that fell into category (a) remained in the study in their entirety. For those in category (b), either the respondent was contacted for clarification, or certain parts of the data were salvaged. However, those projects that fell into category (c), it was felt, were unsalvageable and had to be completely ignored. Fortunately the latter category was only applicable to two projects.

In order to obtain an overview of the responses that now remained from the survey, each question was broken down into a summary of responses. This provided a set of simple statistics to each of the question categories by using such simple tools as averaging, sizing and frequency distributions. The visual interpretations of these, in terms of graphs and tables are presented in section 4.

It was further possible, using simple spreadsheet analysis to highlight two dimensional trends graphically. This was done in order to show the functional relationship between Project Success (ie. for schedule, as well as budget and technical control) and each of the Project Characteristics, as well as each of the Schedule Control Techniques.

3.2.2 Formal Statistical Analysis

Although the above simple trending methods are very visual and will roughly show the existence of functional relationships between success and a single other variable, they have the following shortcomings:

a. They cannot easily be extended to more complex multi - relationships.
b. They do not give a rigorous indication for the strength of the relationship.
c. They do not show the influence of outside factors on the relationship.
d. Relationships are not quantifiable.

In order to overcome the above problems, a formal statistical analysis was undertaken, the express purpose of which, was to either rigorously prove or rigorously disprove the existence of functional relationships between Project Success, Project Characteristics and Schedule Control Techniques.

In order to facilitate such a statistical analysis, the scaling factors in the questionnaire were carefully chosen and set out on numerical scales. This provided a data set of the form illustrated in table 3.1 below.

TABLE 3.1 : Form of the questionnaire data set

Project No.	PROJECT CHARACTERISTICS				SCHEDULE CONTROL		PROJECT SUCCESS		
	Age	Type	Cost	Duration	Technique	Person	Schedule	Cost	Technical
Cont.	Cont.	Disc.	Disc. 1-6	Disc. 1-5	a b c . . j 10 Techn. Disc. 1-3	Disc. 1-8	Disc. 1-5	Disc. 1-5	Disc. 1-5

LEGEND: Cont. = Continuous variable.
Disc. = Discreet variable.

The essential functional relationships which were to be tested with this statistical analysis, were:

1. Success = f(Project Characteristic)
   = f(Age) or f(Type) or f(Cost) or f(Duration)

2. Success = f(Control Technique)
   = f(Techn. 1) or f(Techn. 2)... f(Control Person)

3. Type of Technique = f(Project Characteristic)

4. Success = f{Control Technique = f(Project Characteristic)}

As the primary concern of the investigation was to determine the existence of a relationship, from a set of numerical data, the first natural attempt would be to perform a regression analysis. This would have entailed fitting a specific type of curve to specific data sets and then establishing the "goodness" of this fit (ie. correlation), as well as the strength of this relationship, with a statistical test such as the F-ratio. Such analysis would be extremely tedious if done by hand, but could reasonably simply be performed with aid of a digital computer. In fact, there are several P.C. based computer packages which would perform this operation with ease. There are, however, a number of problems with such a mathematical technique which limit its application. These problems include the following:

a. It is likely that the relationships to be tested would not merely be simple 2 - degree of freedom cases, but more likely multi-factor relationships. This multi-factor regression is of considerably greater complexity and would rule out the use of hand calculation as well as most of the simpler computer packages.
b. It is unlikely that the relationships to be tested would be linear, which may thus require multiple tests on each data correlation with a sophisticated programme. These correlations would have to be performed with different numbers of factors, at different powers, before an acceptable correlation were attained.
c. By the very nature of the questionnaire construction and the questions which had to be asked of the respondents, the majority of the values in the data fields are not continuous. They are in fact, discreet values between small ranges. This does not lend itself well to regression analysis.
d. Certain of the data fields are not only discreet, but are also indicator variables (ie. Project Type). As such, the order of the variables within that specific factor have absolutely no significance, and would thus render a regression meaningless.

For these reasons it did not appear feasible to use a regression analysis in any form (either linear, non-linear, single or multiple). It would be more feasible to use Analysis of Variance (ANOVA) or Categorical Analysis, as these techniques adhere more closely to the requirements of this study. Their application would make it possible to identify the existance of relationships between discreet variables where the ordering is not of significance. Their only limitation would be that they could not quantify the relationship under scrutiny, as a particular mathematical function. This is of limited significance to this study.

In using one of these techniques, the analysis would need to be seen in statistical terms as follows:

> If it can be assumed that the results of the questionnaire have been obtained from independent random sampling and that we have a series of normally distributed populations, given by each of the question categories, then the test to be applied is:
>
> $H_0 : \mu_1 = \mu_2 = \mu_3$
> With $\alpha = 0.05$

The above statement firstly requires that the data was obtained from independent random sampling. This remains strictly a function of the manner in which the survey was conducted. Although the survey <u>was</u> targeted at a specific industry (ie. engineering concerns), the questionnaires were sent out to a wide range of different companies and individuals, in order to insure that the sample population remained as random as possible.

The second requirement of the above statement, is that the responses themselves have normally distributed populations. Although this is difficult to control, one can merely hope that the number of responses obtained are large enough to display normal distributions. This can be checked by examining the frequency distributions of the responses, as displayed in the simple statistics (detailed in section 3.2.1).

Assuming it has now been established that the data has been obtained from independent, random sampling and is normally distributed, the null hypothesis can now be tested using statistical ANOVA or categorical analysis. The difference between the two analyses is the form of the response variable. Essentially, ANOVA strictly requires a continuous response variable, but can roughly be used with a discreet response, while Categorical Analysis is used specifically in the case of discreet response and predictor variables.

In this particular case, the response variables were in most cases reported on discreet scales, from 1 - 5. As ANOVA is a simple technique to perform, and will roughly show the existence of a relationship, it was used as a first pass. This was done in the understanding that the analysis had the limitation that the ANOVA would not show the applicability of the data set, but merely the possible existence of a relationship. In the more strictly correct Categorical Analysis, the group of techniques available have been described as statistical modelling and are aimed at performing a type of discreet regression. The problem with this technique is that, if used, it would probably be required to alter the scales of the questionnaire, so as to make the modelling valid. The reason for this is that the technique indicates the validity of the data being used.

The following three sections have been included in order to describe the statistical analysis procedures in more detail and to suggest why they were applicable to the analysis. They include the Analysis of Variance, the Categorical Analysis and the Log-Linear Modelling.

a. <u>Analysis of Variance</u>

There are two forms of ANOVA, one which checks the variance in the population means of a quantitative response variable against a single qualitative factor (One-Way ANOVA). The second, more complex form of ANOVA, checks the population means of a series of response variables against more than one qualitative factor (Multi-Factor ANOVA).

One-Way ANOVA

Although it is not within the scope of this research to analyse the use of ANOVA, the following needs to be highlighted in respect of the research in this case.

The technique considers a single factor response and attempts to determine not only the size of the variance within a specific population about its mean, but also the variance between each of these population means. It is assumed that the total Sum of the Square (SST) is made up of these two components, which are known as the Sum of Squares Within (SSW) and the Sum of Squares About (SSA). If the variations between population means is very small, in comparison to the variation within each population, then it is unlikely that there is a significant variation of one variable in response to the other. This would mean that the population means are roughly equal compared to the size of the variations within each population. It would thus be said that the null hypothesis, which states that $\mu_1 = \mu_2$, cannot be rejected. In this case, it is unlikely that the response variable is actually a function of the qualitative factor under investigation.

The point at which the null hypothesis may be rejected occurs at the specific level of significance determined by the researcher (in this case at 5%). In order to determine this significance, one makes use of the F-ratio. This assumes, under the the condition of the null hypothesis being true, that the ratio of Mean Squares About (MSA) to the Mean Squares Within (MSW), has as its sampling distribution, the F distribution.

The significance of One-Way ANOVA theory, to this investigation, is that it can be used to test the null hypothesis that Project Success is not related to either, <u>one</u> of the Project Characteristics, or to <u>one</u> of the Project Schedule Control Techniques. It could further be used to test the null hypothesis, that the use of <u>any one</u> of the Control Techniques, is not a function of <u>any one</u> of the Project Characteristics.

This technique was in fact run, using a P.C. based package called Statgraphics, to test the functional relationships outlined above.

The One-Way ANOVA tests provide a valuable indication of the existence of single relationships between the variables under consideration. However, the method only provides a partial picture and as such, it is not fully representative of the actual relationships. It is because of the fact that One-Way ANOVA supposes the response variable to be a function of <u>only one factor</u>, that this is the case. What One-Way ANOVA does not take into account, is that the response variable may be effected by a number of factors, which may combine to have a constructive effect on the whole relationship.

As an example of the above; a One-Way ANOVA test may show that the relationship between Project Success and the use of PERT/CPM are highly significant. However, it is quite conceivable that when PERT/CPM is used together with the Line of Balance technique, or on projects of very small scale, that this relationship does not hold true.

Multi-Factor ANOVA

In order to take account of the effect of multiple factors on the response variable, a Two-Way Analysis of Variance was used. Essentially this technique analyses the effect of one or more qualitative factors on a response variable. In this specific case the cross product of each of the project characteristics and each of the schedule techniques were evaluated against each of the measures of success. As such, the procedure conducted was in fact a Two-Way ANOVA, with the two factors being Project Characteristics and Project Techniques, while the the response was project success.

This analysis was conducted in order to establish whether the techniques chosen, in any specific circumstances, determine the level of success of that project.

Now although the Two-Way ANOVA model may help to portray a model closer to reality, the essential problem with ANOVA itself remains. That is, it is an assumption of the ANOVA model that the response variable is a continuous one, which is not the case here. Although it has been proven that in most cases, this is not a seriously faulty assumption, the model itself does not provide an indication of the validity of the data within the model. This does not mean that the results from such a model should be disregarded, rather that an attempt should be made to corroborate them.

b. <u>Contingency Table</u>

The most strictly correct way of analysing data not conforming to a continuous numeric scale is to use Categorical Analysis. The most straightforward of these techniques is the Contingency table. As such, it was decided to use a contingency analysis on the data to establish whether there was any association between variables.

The rationale involved in this technique is well documented in such references as [8][32][43] and, as such, the following brief summary of the technique should suffice:

Essentially, the frequency of occurrence of one or a number of predictor variables are tabulated against the response variable. The null hypothesis of no association between the response and predictor variables, is equivalent to a model which says that the column and row categories of the table are independent. The null hypothesis can be tested using the Chi-Squared test at a 5% significance.

This type of analysis is usually regarded as an analysis of frequency and requires the data to be in the form of variable frequency counts. If, however, the data is "raw" and not in this frequency format, as in this case, then the frequency information itself needs to first be derived. With the use of the programme Statgraphics, however, the procedure known as Crosstabulation was used to obtain the requisite data format. As such, the significance of the null hypothesis can be tabulated.

This procedure provides an indication of the appropriateness of the data, in that when the predicted frequencies in each category fall below the acceptable level, a warning is given. The only way to overcome this is then to "compress" the scales of the variables, if is not practical to obtain more survey results.

c. <u>Log-Linear Analysis</u>

The above procedure provides an indication of the significance of the null hypothesis, that there is no relationship between the response and predictor variables. It also provides an indication of the validity of the data, both before and after the compression of the data. It does not, however, provide an indication of the form of the relationship. As such, the above procedures, although simpler to implement, are lacking in some respects.

What the log-linear modelling does, is to provide a model, in tabular form, of the expected frequency of occurrence of the relationships, assuming that the null hypothesis is true. If the <u>percentage observed frequency</u> of occurrence, in any one cell of the table, is subtracted from the <u>percentage expected frequency</u> of occurrence of that cell, this leaves what is known as a <u>Standard Residual</u>. The size and sign of this residual is an indication of the deviation of that observation from the null hypothesis, or the degree by which the relationship deviates from the assumption of independence (ie there being no relationship).

The problem with this procedure is, however, that it is only applicable where the observed frequency of occurrence is greater than 5. If this is not the case, it is required that either a greater number of observations be taken to validate the model, or that the size of the model be compressed by reducing the range of one of the scaling factors.

In the first instance, obtaining more observations would not be practical, as the survey was complete. The latter alternative is simple enough (although time consuming), in that it would merely require that the scaling factors of the responses be compressed by one or more factors. That is, if for example the five point scale was; "Very Good, Good, Average, Poor, Very Poor", this scale could be compressed into a three point scale such as; "Above Average, Average, Below Average". The problem with this, is that the condensed scale would not provide as much information as the original scale. Although, it is arguable that less information, which is accurate and valid, is of greater value than more information which is of questionable validity or accuracy.

This being the case, it was decided to run the log-linear model on those relationships in the contingency analysis, where the null hypothesis of independence was rejected and in which the validity of the data could be proved both before and after the compression of the data.

4. RESULTS

The research in this dissertation has essentially been two-pronged. The first method of investigation was a literature survey, undertaken to establish the theoretical approaches adopted in the time/schedule control of engineering projects. The results of this part of the study have been detailed in section 2 of this work (Literature Survey) and will be briefly discussed in the section following this.

The literature survey formed the basis of an investigation into the actual practices which are adopted in the control of engineering projects. The procedure used in this part of the investigation has been detailed in the previous section (3. Research Method), and can be summarised as follows:

- Construct a questionnaire.
- Use the questionnaire in an industrial survey.
- Assemble the responses to the industrial survey.
- Analyse the responses to the industrial survey.

It is the intention of this section, to assemble the responses to the industrial survey, in order to give an indication of the results of the survey itself. In this regard, this section has been divided into three sub-sections. The first one deals with the results of the industrial survey procedure. The second deals with the responses to the questionnaire, in terms of industrial projects of the South Western Cape, and the final sub-section discusses the results of the analysis which were performed on the data obtained in the survey.

4.1 THE SURVEY

The questionnaire was sent out to approximately two hundred individuals throughout industry in the Western Cape during July and August of 1989. Of these, fifty four were completed and returned between September and November of 1989. As such, the response to the survey was about twenty percent.

Each of the questionnaires could potentially provide information on a maximum of five different projects, because of the structuring of the questionnaire. Hence, the actual number of potential projects that could be analysed, would be dependent on the number of projects each respondent was willing to provide information on. Thus, of the fifty four returned questionnaires, there were a potential two hundred and seventy projects (5 x 54). Of this potential number, one hundred and seventy five projects were provided for potential analysis. This in fact gave a sixty five percent response to the questionnaires that were returned. Of these one hundred and seventy five projects, two had to be omitted during closer examination, as a result of serious omissions by the respondents. This project data is provided in Appendix B.

4.2 THE PROJECTS

Due to the structuring of the questionnaire, it was possible to consider the responses in terms of the projects, rather than individuals. This was preferable due to the fact that individuals would quite conceivably be associated with different types, sizes, values and ages of project. As such, the summary statistics for the entire survey are separated into three project categories. The first category, describes the basic structural characteristics of the projects. The second category describes time/schedule control attributes of the projects, and the third category describes the relative success of each of the projects.

4.2.1 <u>Project Characteristics</u>

The project characteristics included in the survey were their age, duration, type and value. The graphs on the following page (figure 4.1) display the frequency distributions for each of these characteristics, for the one hundred and seventy three projects.

A brief description of the highlights of the graphs on the previous page would be:

- **Project Age:** It can be seen from this graph that the distribution is skewed to the left, with the majority of projects having been started between one and seven years ago. Although respondents were asked to provide projects preferably not older than ten years, there were in fact a few older than this.

- **Project Type:** From this graph, it is clear that the majority of projects were classified as General Engineering or Construction type projects, while very few were regarded as being Commissioning and only one was unspecified.

- **Project Duration:** This graph indicates a normal type distribution, with the majority of projects being between one and three years in duration.

- **Project Value:** The indication here was that there were very few smaller projects (value less than R10 000), while most of the projects fell fairly evenly in the categories between R100 000 and greater than R5 million.

4.2.2 Project Control

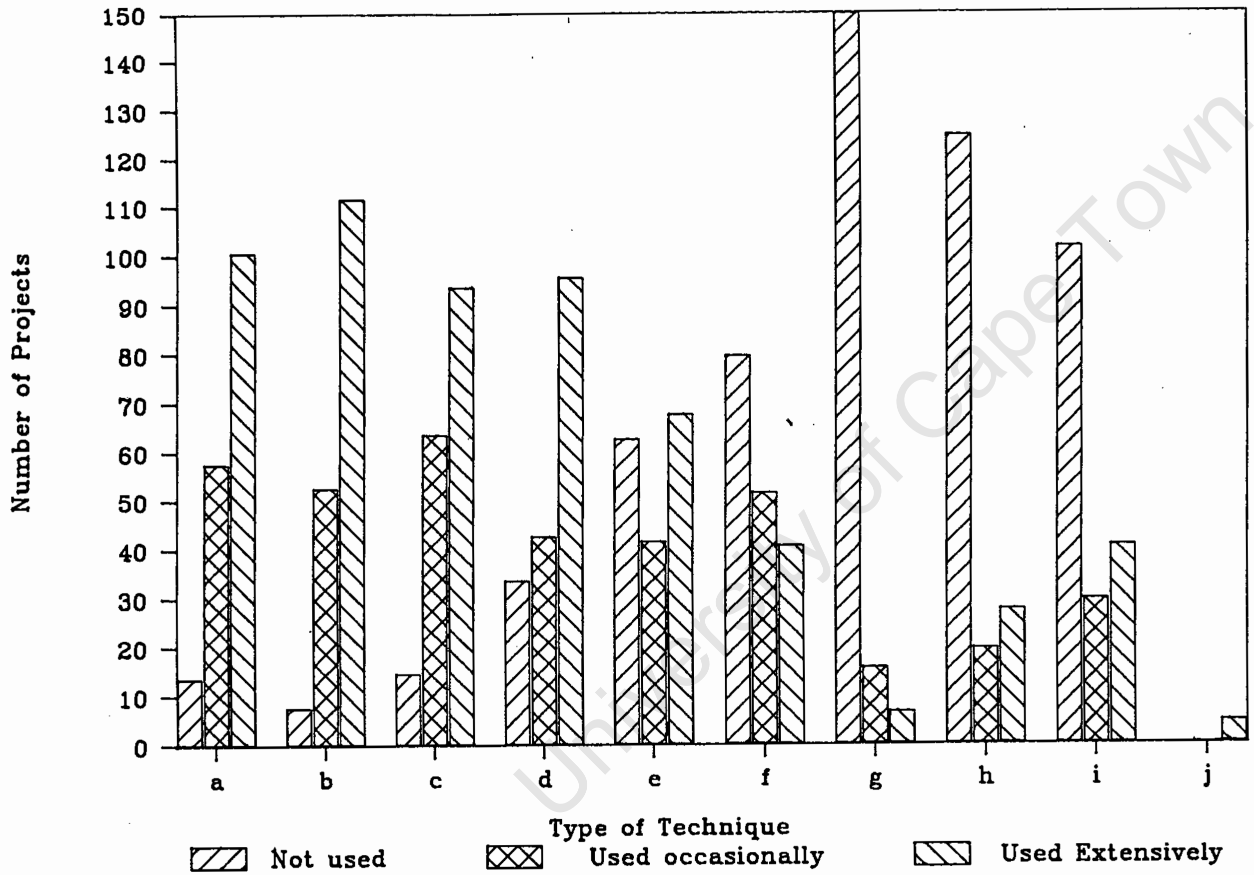
The attributes of project time/schedule control techniques which have been graphed on the following three pages, include; The type of technique/s used and the extent of their use, the authority responsible for the choice of the technique/s, and an indication of what influenced the choice of the specific technique/s.

- **Techniques used:** From figure 4.5, it is evident that the simpler control procedures were used almost without exception, whereas, the more complex techniques, including computer based procedures, were seldom used to any great degree.

- **Authority responsible:** Figure 4.6 seems to indicate that the people responsible for the choice of the techniques used, are predominantly the Project Manager, a Planner and a combination of the two. In a very few instances, an Administrative, or dedicated Planning Department, or Contractor were used, while in no instances was a Financial Department used.

- **Influence on choice:** When questioned as to what project variables affected the choice of technique, figure 4.7 illustrates the responses. It is clear that in most projects, the respondents felt that project Type, Size and Complexity were influencing factors. Also that Management Influence, Intuition and Client Contract, were important in certain instances. An alternative which was identified by a respondent during the survey, was that of Lack of Planning Time, which suggests that because there was minimal time to perform the planning exercise, this could have dictated the technique used.

Figure 4.5 USAGE OF CONTROL TECHNIQUES
(Frequency Distribution)



KEY

(a) Informal Meetings
(b) Formal general meetings
(c) Regular, Formalised reporting
(d) Bar/Gantt charts
(e) Milestones on a WBS
(f) PERT/CPM networks
(g) Line of Balance
(h) Progress "S" curves
(i) Integrated P.C. Package
(j) Other

Figure 4.6

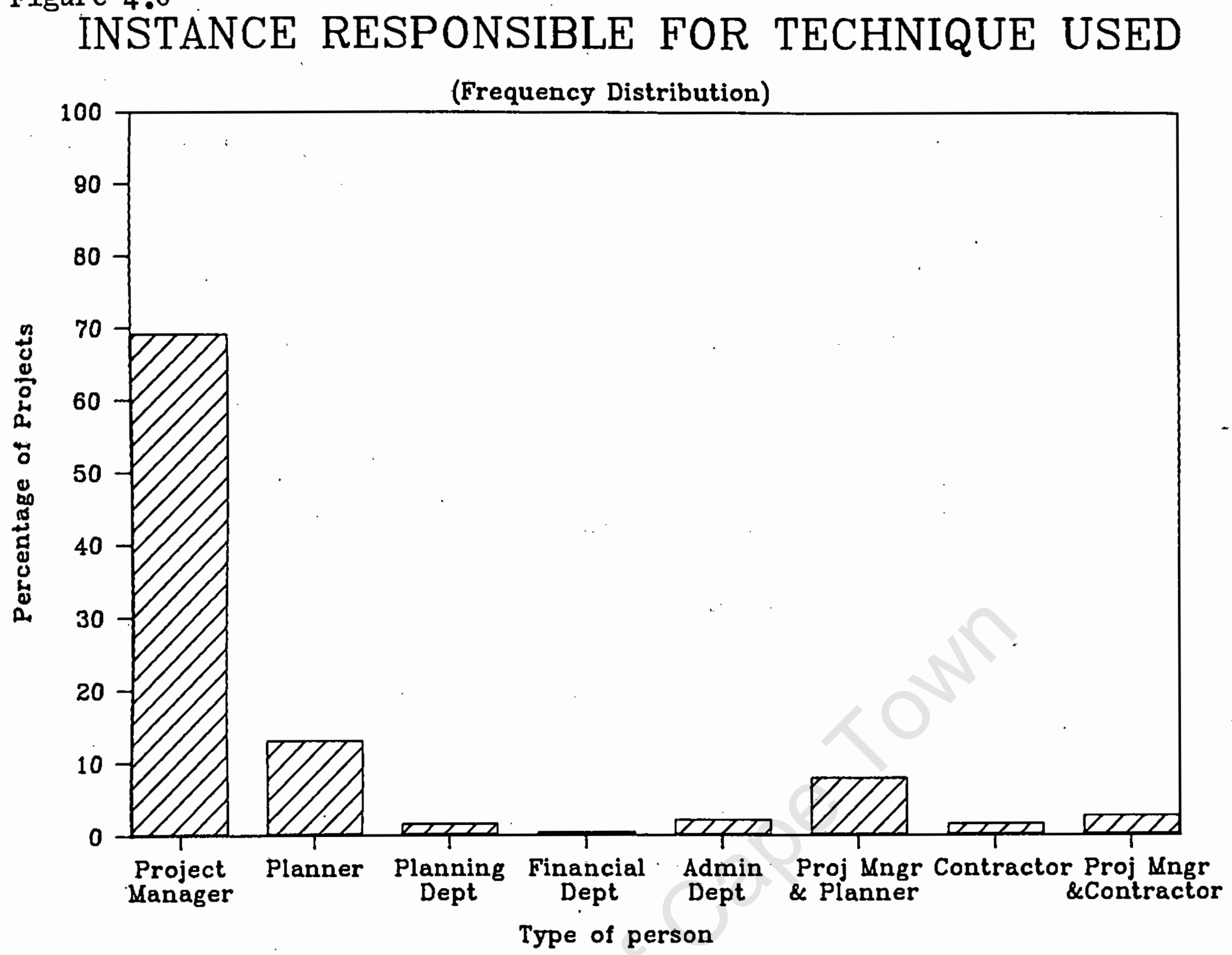
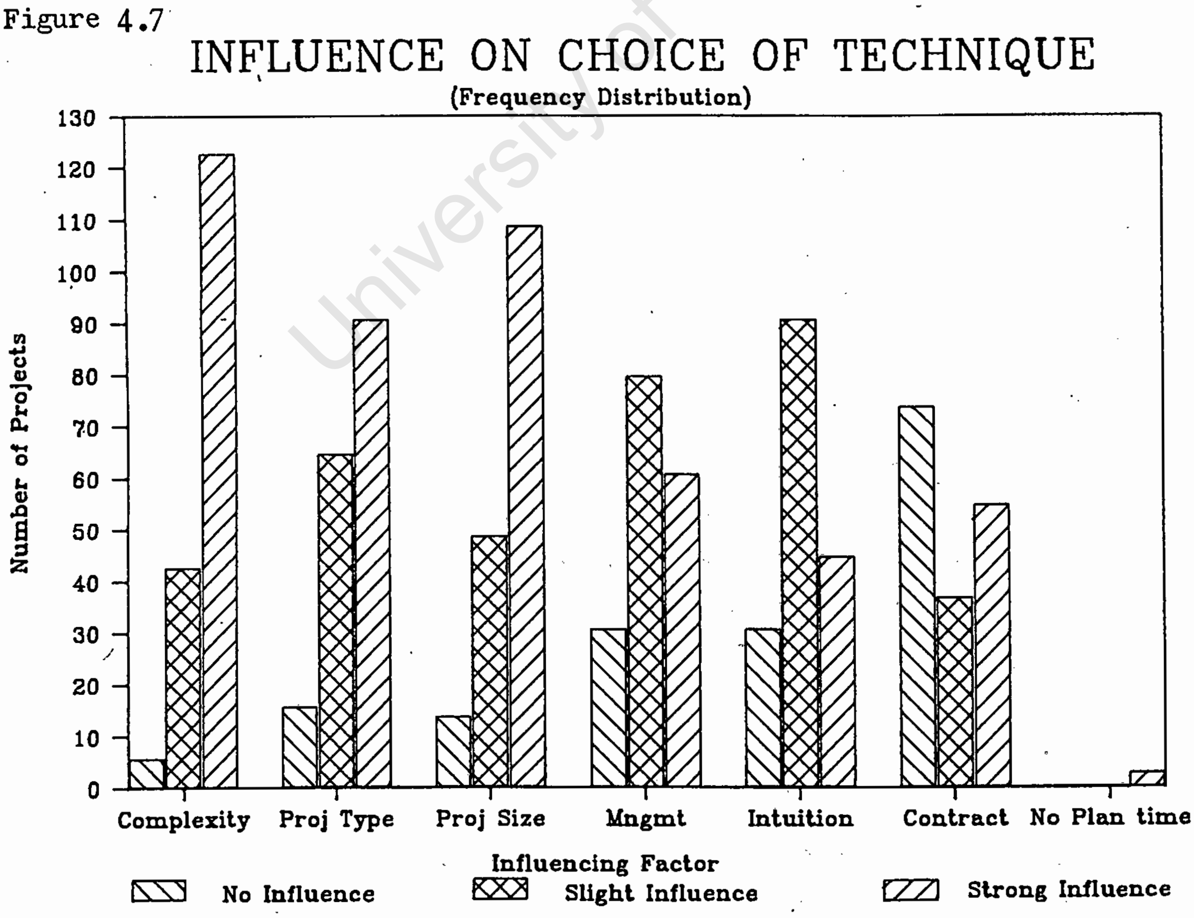


Figure 4.7



regarded as being either too simple, or too complex, or not meaningful to project participants, although these are fairly small percentages.

4.2.3 Project Success

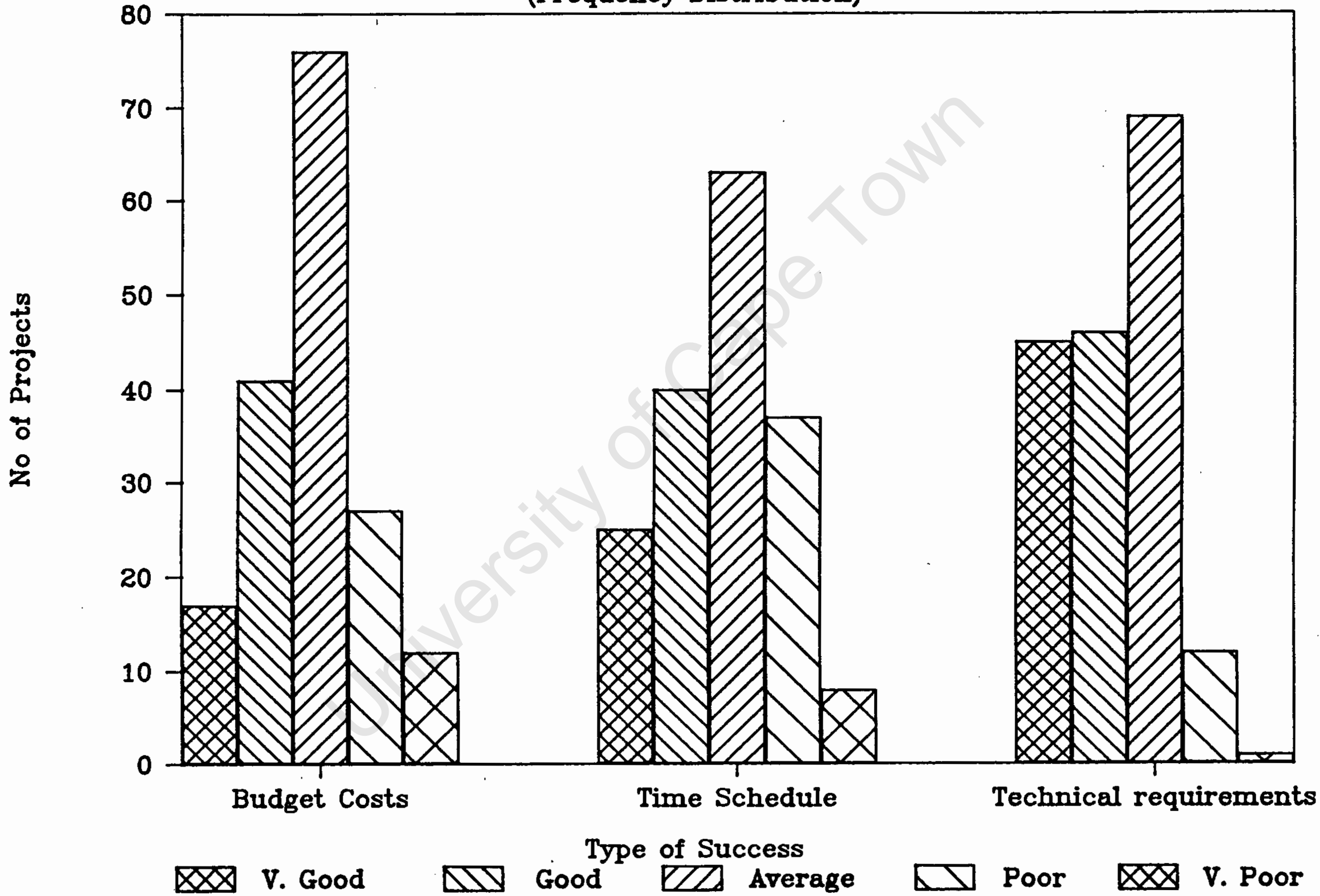
The respondents view of the success of the project remains highly subjective. In order to decrease the degree of subjectivity, the respondents opinion of the relative success of the project on the three major project attributes (Time, Cost, Quality) were examined. The graph in figure 4.8, on the following page, shows the frequency distribution for the relative success of each of the project attributes, namely; Budget, Schedule, Technical.

This graph indicates that both the Budget and Schedule Success frequency distributions are approximately normal. However, the frequency distribution for Technical Success is skewed to the left, indicating that very few projects were regarded as as being technical failures. This could indicate that project managers would be willing to sacrifice both schedule and budget, in order to meet the technical goals of the project.

Figure 4.8

PROJECT SUCCESS

(Frequency Distribution)



4.3 THE ANALYSIS

The results from the survey yielded the responses of the projects indicated above. On these responses, the analysis discussed in section 3 was conducted. As such, the results of this analysis will in turn be presented in this sub-section and discussed in detail in the following section of the dissertation.

4.3.1 Graphical Analysis

In order to analyse the effect which project characteristics and project schedule control attributes have on the perceived success of a project, graphs of success (Budget, Schedule and Technical) against each of the monitored characteristics and control attributes were plotted.

The frequency distribution plots, shown in Appendix B, form a visual expression of which factors influence perceived success, and how the different types of success are influenced differently. It is noticeable from these graphs that schedule control techniques do not only influence the schedule success of a project, but they that also influence the budget and technical success. It can, however, be seen that these graphics are quite difficult to interpret because they attempt to reflect the relationship of three variables.

4.3.2 One-Way ANOVA

The results of the one-way ANOVA tests that were obtained using the Statgraphics computer package, are displayed in Appendix C. The four tables indicate the results of the seventy eight runs performed, in order to test for one-way functional relationships between the different forms of success and both project characteristics and schedule control attributes, as well as the possible relationships between the project characteristics and the schedule control attributes.

Table 4.1 below, has been included in the text as an example of the one-way ANOVA results in Appendix C. In these tables, it must be noted that only those values which display a significance of rejecting the null hypothesis (less than 5% significance with the F-ratio), have been recorded. That is, the values included in the tables are the percentage significance (in fraction form) of the assumption that there is no relation between the variables. Hence if these values are less than 5% (0.05), there is a significant relationship. If the percentage significance is, however, greater than 5%, the assumption of no relationship between the variables is valid, and they have not been included in the table.

Table 4.2: Example table of one-way ANOVA results.

Success = f(Characteristic)

Charact \ Success	Cost	Schedule	Technical
Age	0.059	0.008	-
Type	-	0.002	0.021
Value	-	-	0.005
Duration	0.000	-	-

As an example, the value of 0.002 in the above table, indicates that the hypothesis of no relation between project type and schedule success attained, is 0.2% significant. At this low significance of the null hypothesis it is possible to say that such a relationship is highly significant by the one-way ANOVA test.

4.3.3 Two-Way ANOVA

The four tables in Appendix C 2, display the results of the two-way ANOVA tests conducted. The values displayed in the tables are those of the one hundred and eight runs performed, which tested for possible functional relationships between project success and the cross product of project characteristics and schedule control attributes.

The significance of these tables is that they test for the existance of multiple relationships, whereas the one-way ANOVA tested for one to one relationships. Hence, a significant result in these tables would suggest that the choice of the specific technique, to suit the chosen characteristic, could influence the success (schedule, budget or technical) of the project.

As in the case of the one-way ANOVA modelling, only those values which displayed a significance, from the F-test, which rejected the null hypothesis at 5% significance, have been recorded. As such, the meaning of table 5.1 can be extended to the two-way ANOVA tables in Appendix C 2.

4.3.4 Contingency Analysis

The contingency analysis procedure was the first of two statistical procedures used, which could be described as categorical analysis. The purpose of the test is to more reliably test for the existence of functional relationships between the perceived success of the projects, the characteristics of the projects and their schedule control attributes.

The contingency analysis tests that were performed on the data are presented in Appendix D. It can be noticed from this Appendix, that some two hundred and seventy four cross tabulation tests were performed, in order to test the null hypothesis of no relationship using the Chi-squared statistic.

The reason for this prolific number of tests, was the fact that the data response scales were consecutively compressed for each category of test, in order that the test data could be considered sufficient for its validity to be confirmed. Those values for which the null hypothesis of no relationship were rejected by the Chi-squared test (at 5% significance or less) have been tabulated in Appendix D.

Table 4.3 below, has been included in the text as an example of the results of the contingency analysis in Appendix D. In these tables, it must be noted that only those values which display a significance of rejecting the null hypothesis (less than 5% significance with the Chi-squared test), have been recorded. That is, the values included in the tables are the percentage significance (in fraction form) of the assumption that there is <u>no</u> relation between the variables. Hence, if these values are less than 5% (0.05), there <u>is</u> a significant relationship. If the percentage significance is, however, greater than 5%, the assumption of no relationship between the variables (ie. the null hypothesis) is valid, and they have not been included in the table. One will also notice from figure 4.3 that some of the significant results have been marked with an asterisk (*). The importance of this asterisk is that it provides an indication of the fact that the Chi-squared test highlighted the result as being one which is uncertain because of insufficient data, even although the result itself was significant.

Table 4.3: Example table of contingency analysis results.

Success = f(Project characteristic)

	Cost	Schedule	Technical
Age	-	0.002	-
Type	-	0.030 *	0.002 *
Value	-	-	0.016 *
Duration	0.002	-	-

It must, however, be remembered that although the values in Appendix D <u>do</u> indicate the possible existence of relationships, this is all they do. That is, they do not give an indication of the form of this relationship.

It is also of some interest to note that although these tests are more strictly applicable to the data set than those of the ANOVA, they do provide fairly similar results to the one-way tests indicated in Appendix C. The noticeable difference being that the cross tabulation procedure indicates for which tests the data proves insufficient, to be sure of the validity of the test. As a result, several of the results in the one-way ANOVA which indicate a relationship, may be false because of insufficient data.

4.3.5 Log-Linear Analysis

The second of the categorical analyses is that of the Log-linear Modelling. The purpose of this is to provide some indication of the form of the relationships, indicated as being probably in existence from the contingency analysis.

Table 4.4 : Example table of Log-linear Model results

Network techniques = f(Value)

	VALUE		
	< R1mil	R1-R5mil	> R5mil
Not used	+2.0	-0.1	-2.3
Occasional use	+0.4	+0.5	-1.0
Extensive use	-2.3	-0.5	+3.0

The infrequent use of network techniques in projects of value less than R1 million, is more pronounced than independence would predict.

Table 4.4 is an example of the tables produced from these tests which have been included in Appendix D. They provide an indication of the difference between the observed and expected (calculated) frequency of occurrence of observation, within a specific set of relationships. The values in these tables are known as the standard residuals, the magnitude and sign of which, at specific positions within the table, provide an indication of the form of the particular relationship being modelled. Besides each of these tables in Appendix D, there has been included a possible interpretation of the form of the relationship, as a short summary.

5. DISCUSSION

In this section, the objectives are to summarise the major findings of the literature survey and to discuss their relevance to the results of the industrial survey.

With these objectives in mind, three topics will be discussed in separate sub-sections. The individual issues concerned in each of these discussions will be as follows:

- **Literature Findings:** This sub-section discusses the conclusions drawn from the literature on such issues as the Systems View, the use of Structural Variables and the application of Control Methods.
- **Industrial Survey:** This sub-section discusses the limitations of the industrial survey, the conclusions apparent from viewing the survey responses and the trends made apparent through the statistical analysis.
- **Theory and Practice:** This sub-section discusses the relevance of the literature theory in terms of the industrial findings. It further discusses the applicability of the research findings to practising project managers and highlights areas for further research.

5.1 LITERATURE FINDINGS

It should be clear from the literature survey of section 2. that there is an abundance of general project management literature in current books and periodicals. The literature appears in several guises and views the topic of project management in several different ways. In order to fully understand the topic of time/schedule control within project management, it is necessary that one should be aware of such things as:

- The place of the control function in the management of engineering projects in general.
- The relation of this function to the characteristics of the project and the environment in which the project finds itself.

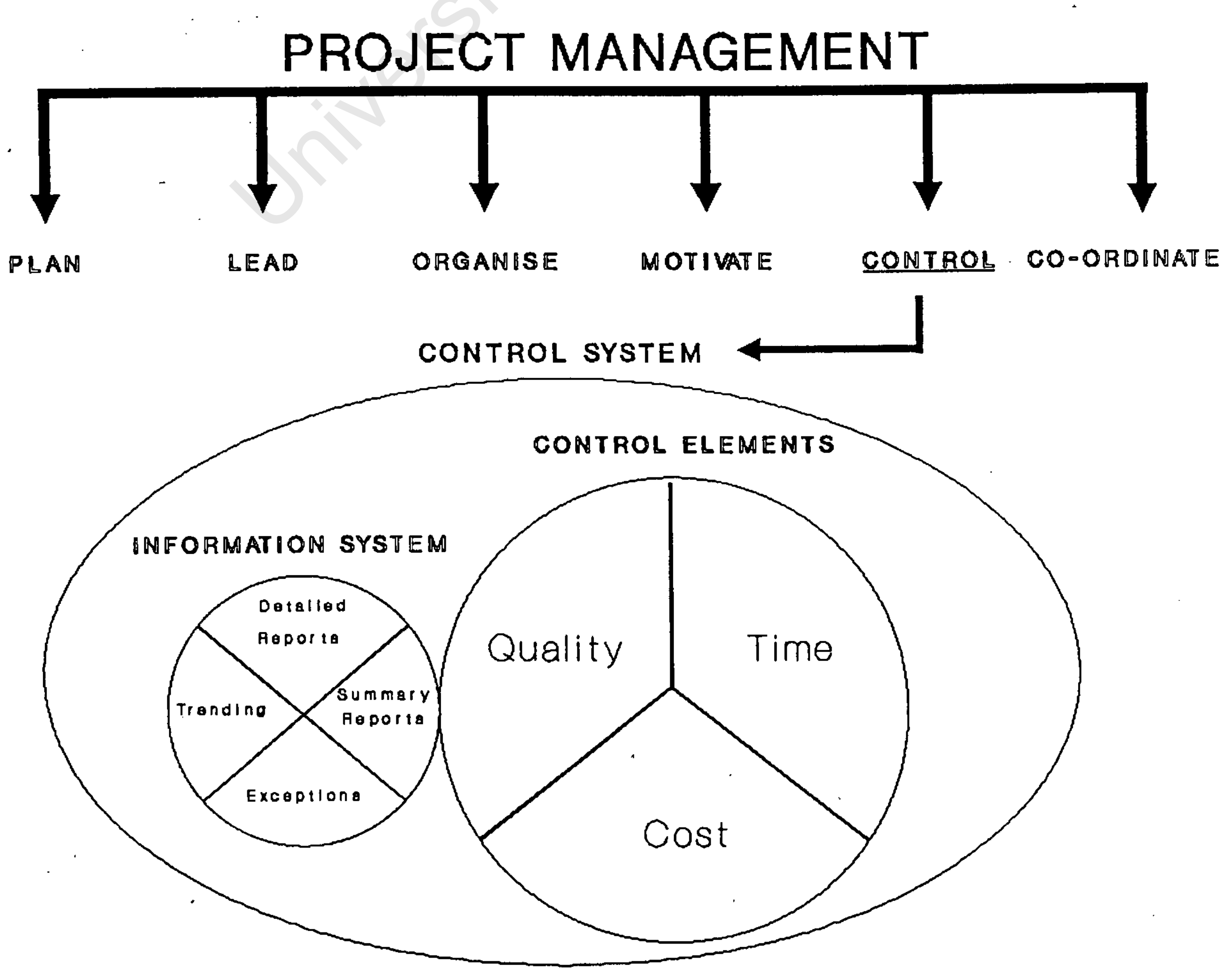
- The procedures involved in ensuring successful execution of the time/schedule control function and ultimate success of the project.

Although these issues have been discussed at some length in section 2. of this report (from the viewpoint of several authors), a short summary of the conclusions is required. In order to do this, the theory that has been crystalized from the fragmented literature, will discussed in terms of the three perspectives which the references used. These included the Systems View, the Structural Attributes and the Methods Approach.

5.1.1 The Systems View

Possibly the best way to place time/schedule control of projects into perspective, is to consider the illustration of figure 5.1 which has been developed from the literature to identify this researcher's understanding of the

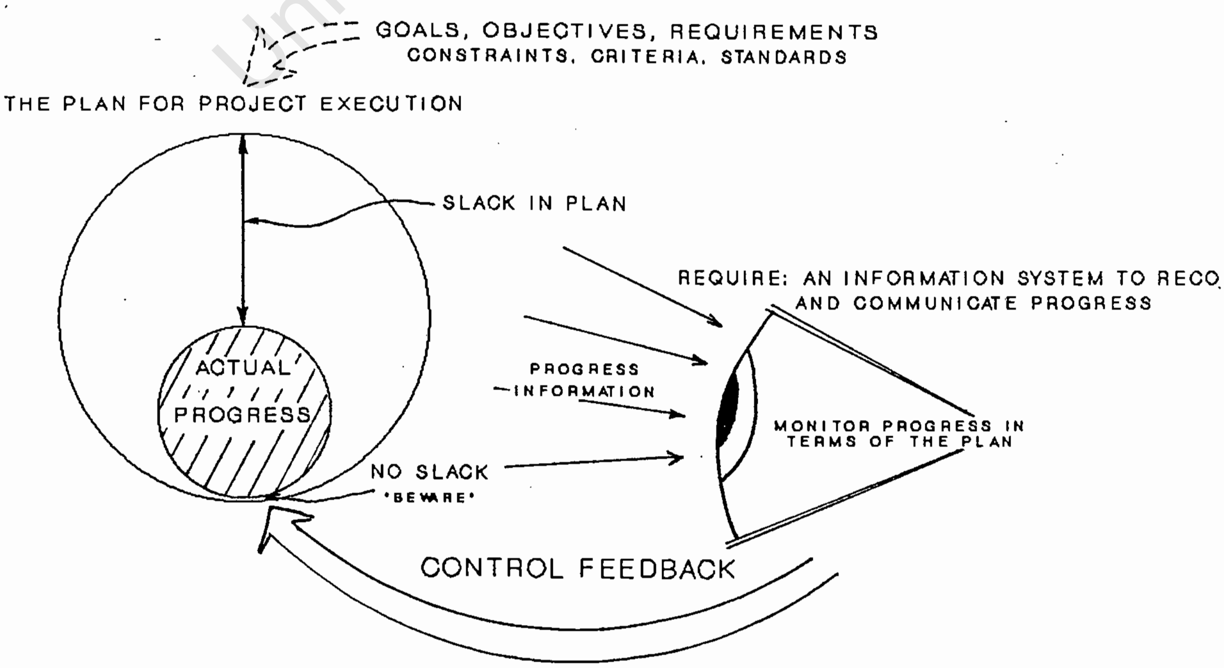
Figure 5.1 : The project management system.



operation of a project management system. This figure illustrates that the control function of the project manager is merely one of his primary tasks. It may not be his priority throughout the life cycle of the project and the attention paid to it will be in continual conflict with that of his other functions. It is further clarified in this figure, that the mechanism by which the project manager will control his project, can be termed the control system. This is made up of the <u>elements</u> which are to be controlled and the <u>information system</u> which drives the control (as indicated by the arrows around the Information & Control System wheels in figure 5.1). Besides the fact that project control is <u>one of the management facets</u> in the project, it is illustrated in figure 5.1 that "time" control is merely <u>one of the elements of control</u> which require consideration and may, or may not, be the most important one.

Figure 5.2 has been developed for this dissertation as it considers more closely the issue under review in this research, that is the mechanism of the "control system".

Figure 5.2 : Time/schedule control system - a model.



PURPOSE: TO KEEP ACTUAL PROGRESS WITH THE LIMITS OF THE PLAN BY CONTROL ACTION. NOT BY ALTERING PLAN.

What this portrays, is that a time/schedule control system is made up of three functions. These being the planning function, the monitoring function and the control function. It is apparent from this figure that when considering time/schedule control of projects, it is not possible to isolate the control function alone when it is the whole system which is facilitating such control.

This figure shows that the execution plan is made up of certain goals, objectives, standards, requirements, constraints and criteria, laid down prior to project commencement. It further shows, that during project execution an attempt is made to maintain the actual progress within the confines of the planned boundaries. The monitoring function then observes the actual progress in relation to planned objectives, and reports this information. Such planning and monitoring functions are completely inconsequential if no effective control function exists, to close the control system loop. It is this control feedback action which alters the course of the project, in order that actual progress remains within the confines of the plan and in order that the plan is kept current. It is effective information gathering and communication that drives this control loop.

5.1.2 The Project Structural Factors

The make-up of a project has been variously described in literature as being those elements in the project which determine the structural, environmental, situational, or characteristic variables, which constitute any project. Such examples as; project manager authority, organisational structure, project duration, management support, project type, and a host of others have been put forward in the literature as determining the structural dimensions of a project. This research suggests that all of these variables are relevant, to a greater or lesser degree, but that there can be an enormous number of such variables. What has been done here, is to assume that the structural dimensions of a project can be divided into two sub-sections, namely; environmental variables and characteristic variables. The distinction between them being that there are only a few characteristics of a project (those identified here being; project type, age, size, complexity and duration), while there are a multitude of environments in which a project, could find itself.

Such a distinction is important to this research, as it is only the characteristic variables which have been included during the industrial survey. Furthermore, this survey fixed certain of the environmental variables, in which projects having particular characteristics can exist. These are the <u>industrial/engineering environment</u> of the <u>South Western Cape</u>. This was not due to an oversight, but rather a calculated omission for the following reasons:

- To constrain the scope of the practical survey, to make it of some relevance to an engineering dissertation.
- Those variables regarded as environmental in nature, are too numerous to be properly investigated in an industrial survey of the type used in this case.
- After considerable investigation, the five variables, mentioned above, were the only ones which were deemed to be worthy of consideration.
- It is easier to accurately determine project characteristics from a questionnaire type of survey, than it is to determine environmental variables, as there is considerably less subjectivity required from the respondent.
- In literature, it is apparent that no-one has previously investigated this distinction.

With these structural constraints on the industrial survey, there are two points that must be made clear:

a. A comprehensive model relating project success, the schedule control mechanism used and all the structural attributes, cannot fully be developed.
b. It should not be construed that the characteristic variables are more important than the structural ones. It should merely be noted that this distinction exists and that it has constrained this research.

What has been suggested in the literature, is that the structural dimensions of a project have some bearing on the choice of a control system used in the project, and its ultimate success. It remains one of the objectives of this research to establish whether such a suggestion is founded or not.

5.1.3 <u>The Methods Approach</u>

In the previous two sub-sections it was attempted to highlight the essential information that has been drawn from the literature. This sub-section will briefly discuss some conclusions which are apparent from this literature, concerning time/schedule control tools.

a. The most important distinction that has become evident, regards the <u>nature of a control technique</u>. What are most often regarded in the literature as "control" techniques, are in actual fact merely planning or monitoring procedures, used to aid the project manager in making informed control decisions.

b. <u>There are several methods</u>, procedures, techniques and heuristics described in the literature which could be used individually, or in combination, to provide the monitoring information required to carry out informed control action to the project. These techniques range from informal meetings and walking around, to simple planned versus progress graphics, to complex network analysis packages capable of integrating optimised planning routines with schedule tracking facilities.

Despite the many techniques available to the project manager, there are very few authors who have recognised that there is no <u>one</u> correct set of procedures, which should be used on all projects. The problem, it would seem, is that most authors are so fascinated by the success of a particular approach, or so deeply engrossed in the mathematical rigor of a specific technique, that they seldom consider the structural variables associated with the applicability of the technique (ie. project characteristics and environment).

c. In the literature, reference was seldom made to a specific technique without there being at least an inference as to the technique's worth in terms of improved <u>project success</u>. What is equally rare is to find that the perceived success of the specific technique has been qualified, to highlight its applicability with associated environmental or characteristic variables.

d. There are very few authors who openly say that <u>the computer</u> does not have at least some place in project management. However, the misconception that the choice of project control system is synonymous with choosing a computer package which will perform the required project control, should be made clear. In the first place, a computer package can only provide information to aid a manager in his control decisions and cannot provide the control. This remains in the domain of the project manager. Secondly, if the manager were to understand the dynamics of the control system, described in section 5.1.1 above, he would realise that there is considerably more to controlling the project's time/schedule than could be addressed by a computer.

e. The computer <u>can</u> be used, in certain instances, to aid the project manager in developing the required level of control, either as a database management system, or by performing the numerical processing such as network optimization, or in the creation of communication graphics. It must, however, be stressed that it is the project manager who manages the project, and <u>not</u> a computer or computer applications package.

f. When techniques are chosen to aid the project manager as control guides, they should be selected mindful of whether or not they will require the use of a computer. If it is required to make such a commitment, the project manager should realise that there is more than a financial commitment, in terms of computer hardware and software. He should realise that there is a related commitment in terms of the man-hours required to input the required information in order to keep the information current. Unless this is done, it is unlikely that this tool will remain a meaningful control aid and may well become an expensive white elephant.

5.2 INDUSTRIAL SURVEY

The mailed industrial survey sent to engineering and industrial concerns in the South Western Cape, during August of 1989, was as a culmination of the literature survey conducted in preceding months. This literature survey, provided the background to the environment in which project time/schedule control procedures are used. It further provided an insight into the effect which structural variables could have on the choice of control techniques and project success, as well as the usefulness of various techniques in aiding project time/schedule control.

The purpose of the industrial survey was to solicit real world information concerning two particular issues. These issues included:

a. The actual industrial practices of the South Western Cape concerning time/schedule control.
b. The relation between project success, project structural attributes, and time/schedule control techniques used.

The method used in the industrial survey, and in the processing of the response to this survey, have been laid out in earlier sections (namely sect. 3. and 4. respectively). It now remains to discuss the limitations of the survey, as well as the trends which are evident in the responses and in the statistical results. This will enable a comparison to be made, between the theory obtained in the literature survey and the actual practice.

5.2.1 Survey Limitations

Before analysing and discussing the results obtained from the industrial survey, it is important to take an objective overview of the limitations of the survey. This is aimed at placing the results obtained into perspective, such that during the discussion, the true value of the results will be evident. These limitations have been divided into three parts, namely considerations pertaining to the survey procedure, to the questionnaire and its construction, and to the analysis performed on the resulting responses. They have been fully detailed in Appendix E. and are summarised below.

a. **Survey Procedure:**
These limitations concern the fact that the industrial survey, was a mailed questionnaire sent out to industry in the South Western Cape. As a result of this, there are doubts as to how representative the survey was of the required response and of whether the there exist self-bias in the returns.

b. **Questionnaire Construction:**
These limitations arise as a result of the construction of the questionnaire. They include the fact that the survey contained questions from a second researcher, that it was fairly long and that the questions themselves required a degree of interpretation.

c. **Data Analysis:**
There are several limitations with the data analysis that was performed. These include a database which displays certain inadequacies, as well as a series of statistical procedures which are not fully capable of providing all the requisite information.

5.2.2 The Survey Response

The first objective of the industrial survey was to determine the actual time/schedule control practices of the South Western Cape. What is uncertain, is whether the data obtained is representative of the target. This is difficult to determine, all that could be done in this case, was to send out the questionnaire as widely as possibly and to perform follow-up interviews, in order to highlight any major discrepancies and serious self-bias.

All such precautions were taken and the indications from the selected follow-up interviews and discussions indicated no serious problems. It will, therefore, be assumed that the survey provides a fair indication of a general cross-section of engineering projects in the South Western Cape, performed over approximately the last ten years.

In order to gain a rough impression of the practices of the South Western Cape, the three topics covered in the questionnaire can be reviewed. These topics included the characteristics of the projects, the time/schedule control methods used on the projects and the success attained. The results of the survey, on each of these topics, have been set out graphically and explained in section 4 of this report. It will thus suffice to give brief mention to each of these in the text which follows, in order to provide a recap of the practices of the South Western Cape.

a. **Project characteristics**

Viewing the graphs of the frequency distributions for the four project characteristics (Section 4, Figures 4.1 to 4.4) provides a general insight into the nature of the projects returned for analysis. These graphs indicate that very few research and commissioning projects were encountered, that the majority of the projects had a duration between one and three years and value in excess of R100 000 and that most were conducted in the last five years.

It is acknowledged that these characteristics may not be indicative of the general nature of projects in the South Western Cape. They can, however, be used as a guide in the absence of a larger database.

b. **Time/Schedule Control Methods**

A summary of the results (in section 4), displaying the frequency of use of time/schedule control techniques on the projects, is provided by figure 5.1 below. This table shows that simpler written and verbal reporting techniques were extensively used, while the slightly more analytically inclined techniques were not. This could indicate the general "state of the art", as practised in the industry of the South Western Cape at this time.

None of the more obscure techniques described in literature were encountered in the questionnaire and the only response which fell into the "other" question

Table 5.1: Frequency of Application of Techniques

FREQUENCY OF APPLICATION	TECHNIQUE
Very Frequently	Meetings and reports.
Frequently	Bar/Gantt charts.
Average Frequency	Milestones & Networks.
Infrequently	"S" curves & Computer applications
Very Infrequently	Line of balance.

category, in fact turned out to be a simple computer application. In the follow-up interviews, one interesting application was encountered, which was a self-styled computer based spreadsheet application. It was used on a construction and commissioning project and made use of man-hour progress and productivity indices compared to original estimates, to produce an "S" curve which provided an indication of work progress. In general, however, the level of sophistication of the techniques in the South Western Cape, was nowhere near that displayed in the literature. Indeed, this was clear from follow-up interviews in which it was discovered that there was not even a general understanding of techniques such as network analysis, Line of Balance and "S" curves.

Other questions put to the respondents were aimed at establishing who had been responsible for the setting up of the control system, why they had chosen the specific techniques, and how effective they had regarded the techniques as being when applied to a specific project. From these broad questions the following significant facts are summarised:

- The project manager, or a planner, were almost exclusively responsible for the choice of the time/ schedule control techniques.

- Issues which most strongly affected the choice of control techniques were; project type, size and complexity (all project characteristics). Other project environmental variables played a lesser role.
- Techniques chosen for each project had been specially adapted to meet their requirements. As such, the general consensus was that the techniques had not been too complex, were regarded as being meaningful to the project participants, were fairly easy to institute, were in general applied throughout the duration of the project and had achieved the required level of schedule control.

c. **Project Success**

The respondent view of the relative success of a project, is an issue which is open to such error as; subjectivity, self-biasing and blatant dishonesty. To ensure respondent honesty and eliminate self-bias through selective choice of projects is not possible, as this remains at his discretion in such a survey. However, the matter of respondent subjectivity was addressed to some extent by breaking down the term "success" into its budget, time and quality facets.

This yielded some fairly significant points. The first, is that in the case of the budget and time/schedule success, the frequency distributions displayed were normal in form and centred around the "average success" measure. This implies that the respondents were not particularly biased in their choice of projects on which to report (on the grounds of success at least).

The frequency distribution for technical success, however, displayed a distribution which was skewed to the left. This indicates that the technical success of the projects were, in general, better than the budget or schedule success. This could imply that:

- The respondents found the division of project success into the budget, schedule and technical facets, to be relevant, as all the distributions were not of the same form.
- Not all respondents were so neutral in their assessment of project success, as to rate all projects as being of "average success".
- Project managers are forced to forego budget or schedule in order to meet the projects technical requirements.

5.2.3 <u>The Functional Analysis</u>

The second objective of the industrial survey was to establish whether there exits some form of functional relationship between the characteristics of the project, the time/schedule control techniques used and the "success" attained in that project. In this regard, the analysis described in section 3. will be discussed according to the procedure used. These procedures include; a Graphical Analysis, an Analysis of Variance (One and Two Way ANOVA) and Categorical Analysis or Analysis of Frequency (namely; contingency tables and log linear modelling).

The primary objective of <u>all</u> of these techniques is to determine the existence of functional relationships between the variables. The results obtained from each of the statistical tests are, therefore, all related. As such, it has been decided not to discuss the results of each of the procedures individually and in isolation from each other, but to consider the analysis procedures together, in order to establish the existance of each of the relationships.

The relationships that have been intimated at, during the literature survey, were set out in section 3.2.2. They include:

a) Is Success = f (Project Characteristic) ?

b) Is Success = f (Time/Schedule control technique used) ?

c) Is Time/Schedule control technique = f (Project Characteristic) ?

d) Is Success = f {Time/Schedule control = f (Project Characteristic)} ?

The significance in the establishment of such functions, is that they could provide an insight into the time/schedule control practices of the South Western Cape. They may also provide and insight into <u>what</u> characteristics and techniques have had (and most likely will continue to have) an influence on the successful implementation of projects, and <u>how</u> they influence the success of such projects. In the text which follows, each of the above relationships will be discussed in greater detail (in separate sub-sections). Evidence of the implications of the relationships will be provided from the results of the statistical analysis on the survey data.

a. <u>Success and Project Characteristics</u>

The question that is asked of the survey data in this case, is whether the perceived success of the projects were in any way related to their characteristics (age, type, duration or value). If it can be assumed that the data from the survey is fairly representative of the target (engineering/industrial concerns of the South Western Cape) and that its applicability can be geographically extended, then knowledge of this functional relationship will provide the manager of a project, having specific characteristics, with the aspects he should be weary of. That is, it will be possible to say whether projects having a specific type, duration and value are more susceptible to poorer or improved budget, schedule or technical success.

Although project age has been included as a characteristic variable, it is different to the other characteristics. The reason for this is that it is historic in nature, while the other variables are not. As such, its importance as a characteristic variable is not as great as the other three.

On viewing the results of appendices B, C and D (Graphics, ANOVA, and Contingency analysis), the first point that is apparent, is that the relationship is neither fully proven or disproven. The reason for this being that there are not significant relationships in evidence for all variables. The contingency table of Appendix D indicate (table 6) that the variables which show fairly conclusive evidence of supporting this relationship are :

- Budget Success = f (Age, Duration)
- Schedule Success = f (Type, Value)

This appendix also highlights the possible existence of a relationship Technical Success = f (Type), but this remains inconclusive because of insufficient data. The one-way ANOVA of Appendix C (table 1) provides essentially the same results, only it gives no indication of the validity of the data for the extra results provided on technical success, which the cross tabulation of Appendix D does.

Although the above mentioned appendices provide an indication of the possible existence of specific success - characteristic relationships, they give no indication of the form of these relationships. For this, one is required to consider the graphics of Appendix B and the results of the log-linear modeling from Appendix D (tables 13, 14, 18, 19, 20). From these results the following is apparent:

- The budget success of projects has improved in recent times and that it is better on short duration projects.

- The improved schedule success has been associated with research, development and engineering projects
- In terms of project value the results are not as clear. It appears that those projects having a financial value less than R1 million and greater than R5 million had improved schedule success.

Of these results, there are some that require further attention. Firstly, the fact that research and development projects have better schedule success than such project types as construction, would seem to be an anomaly. This could be explained by the fact that the respondents who assess the "success" of construction projects, are far more strict in their assessment of such projects than those respondents who have dealt with research and development projects, which are in general far more loosely controlled in schedule (by their very nature).
Secondly, there would seem to be no apparent reason for projects of financial value between R1 million and R5 million having poorer schedule success, other than the fact that between this range the projects are possibly now no longer simple enough to have schedules controlled by simple techniques alone, yet not quite complex enough to demand rigorous use of the more complex ones.

Thirdly, the fact that technical success was not found to be <u>significantly</u> associated to any of the characteristics, may not mean that there is no association at all. It may well be that the relationships in Appendix D (tables 1-5) are significant but require a larger database to prove their validity.

In general, it can be said that the one-to-one relationships between a project's success and its characteristics has not been proven to any significant degree. There are some indications to suggest this, but these are weak and open to varied interpretation.

b. <u>Success and Project Time/Schedule Control</u>

Of significance to the research, is whether there is some well defined link between the ultimate success of the project and the approach adopted to control time/schedule. The two elements of control which were investigated, were the techniques used to control time/schedule and the authority responsible for the choice of the control techniques. The purpose behind such an endeavour was to aid the project manager in choosing those techniques which have proved most successful, or to allow those entities who have had the greatest success, to decide on the choice of technique.

Once again it can be seen that the results of the ANOVA in Appendix C (table 3) roughly correspond to those of the more strictly correct contingency analysis in Appendix D (tables 2, 9, 11). In general one can see that the success - time/schedule control techniques relationship, has not been conclusively proven. Only isolated techniques could be related to some of the measures of success and of these only two could be highlighted as being adequately significant without the danger of data inadequacies.

The two significant relationships displayed in Appendix D (tables 2, 9, 11) stated that the use of project "S" curves are related to budget success, while the use of the milestone technique is related to schedule success.

On viewing the Log-linear Models in Appendix D (tables 15, 21) and the two graphs in Appendix B, it is apparent that neither of them is very strong. The rough indications, concerning the form of the relationship are:

- That the more extensive use of "S" curves will lead to improved budget success.

- That the extensive use of milestone techniques could lead to either high or low, rather than average, schedule success.

All that can really be concluded from this is that a straight one to one relationship of success and technique is not in evidence. This is probably because the success of the techniques depends on the specific structural variables (characteristic and environmental) associated with the project.

Considering the relationship between the authority responsible for the techniques used and the ultimate success of the project, it is clear from Appendices C (table 3) and Appendix D (tables 4 & 8), that these results are as equally inconclusive as those of the control techniques. It is only when the scale of the data is altered and compressed, that at least some significant results are reflected. Essentially the results state (when viewed in conjunction with the log-linear models of Appendix D {tables 16, 17, 22}), that:

- Both budget and technical success were improved when a planner had at least some input into the choice of technique.
- Budget success alone appears to be poorer when the project manager had an influence on the choice.

The fact that a planner showed signs of positively influencing budget and technical success, could be regarded as evidence that such a multi-disciplined person, who is able to objectively assess project requirements, can provide positive results. Although budget success is negatively related to the influence of the project manager, it is unlikely that this is an indictment on his ability to choose the correct time/schedule control procedures to manage his project. On the contrary, he is the one who must implicitly believe in, and thoroughly grasp, the importance and place of such techniques in controlling not only the time/schedule of the project, but also its budget and technical aspects. What this result can be interpreted as highlighting, is the importance of involving other project participants in the choice of techniques, so that it is not only the project manager himself who understands the significance of properly controlling project schedule and hence influencing project success.

It would be difficult to conclude that there is a general, one to one relationship between either the types of time/schedule control techniques used, or the authority responsible for choosing such techniques, and the eventual success of the project. All that can be said, is that there is slight evidence to suggest this. However, it is very likely that the situational variables (characteristic and environmental) play a more important role in determining the success of the project, when using certain techniques, than was originally anticipated. It is thus likely that a much more sophisticated relationship exists, which will include not only the techniques as a function of success, but also the situational variables. This lack of evidence to support a one to one relationship is in itself highly significant, as it suggests that:

- The present investigation considers a scenario that involves only part of the problem of selecting appropriate techniques.
- The time/schedule control requirements for a project, are very different to main stream organisational requirements. This is possibly why the choice of financial, administration, and planning departments were shown to have such little influence on the success of the projects.

c. <u>Project Time/Schedule Control and Characteristics</u>

In this part of the data analysis, the relationship between techniques used by the respondents to control time/schedule and the specific project characteristics was investigated. The significance of such an analysis is that it provides an insight into the practices adopted in the target survey (ie. Engineering/Industrial projects in the South Western Cape over the last ten years) and not of preferred practice. That is, it provides the researcher with an indication of whether project characteristics influenced the choice of technique. This could be compared to the direct question asked of the respondents in the survey questionnaire (ie. Appendix A question 8).

Comparing the results obtained from the one-way ANOVA (Appendix C {table 4}) with those of the contingency analysis in Appendix D (table 3), it is seen that there are similar strong indications to support this relationship in both cases. What the contingency tables here indicate, which the ANOVA does not, is that in a considerable number of cases, the validity of the relationships are questionable due to data inadequacies. It was possible to compress the scales of the contingency tables as described in section 2, and to once again assess the relationships. Analysing these relationships (as shown in Appendix D {tables 7, 10, 12}) again, still reveals evidence to support their existence, but with fewer warnings of data inadequacies.

Considering these three tables in Appendix D (Technique vs Characteristic) more closely, it is apparent that certain characteristics are more generally related to the time/schedule control techniques than others. It appears that:

- The project's financial "value" and "duration", were in general the strongest characteristic influences on the types of technique chosen.

- The "type" of project generally showed inconclusive results.
- Project "age" showed the least evidence of association to technique used.

Comparing the above results with the perceptions of respondents on direct questioning, in figure 4.7 of the previous section, it is clear that the characteristic variables; size, type and complexity (associated roughly to duration in this instance) were widely regarded as being the major influences on choice of technique. Certain environmental variables such as management influence, intuition and stipulations of contract, played a markedly lesser role. This cross check on the statistical analysis suggests that the respondents were fairly consistent in their answering of the questions and hence it provides some confidence for the data obtained.

Considering the contingency tables in the light of the Log-linear Modeling, allows the form of the relationships to be determined. The relevant Log-linear models, together with a short comment on each, appear in Appendix D (from table 23 to table 44). The functions selected from the contingency tables of Appendix D (tables 3, 7, 10, 12) are those for which the Chi-squared test indicated a significance level less than 5%.

In considering project "<u>financial value</u>" versus control technique (tables 34 - 41), the following is evident:

- The more extensive use of techniques such as bar/Gantt charts, milestones on a work breakdown structure (WBS), network analysis, project "S" curves, and computer applications, are associated with the higher value projects (R1-R5 million and upward). Further, their use seems to be occasional at values less than this.

- The extensive use of formal meetings and reports, is related to higher value projects. In the instances when they are not used at all, the indication is that this is not associated to project value.
- The line of balance (LOB) technique indicates a possible relationship in the contingency tables, however, this relationship is not conclusive in the Log-linear Model. This spurious result, could be due to the fact that some respondents thought that a technique they had been using was LOB, when this was not actually the case. That is, it became apparent during the follow-up interviews that this is not a widely known technique in certain sectors of industry. As such, the results for this technique may well prove erroneous.

If one considers the Log-linear Models for the characteristic variable "<u>duration</u>" versus control technique (tables 28 - 33), the following is evident :

- The more extensive use of techniques such as milestones on a WBS, network analysis, project "S" curves, formal reporting and computer applications, are associated to the longer duration projects (1-3 years and longer). For durations less than this, their use appears more likely to be occasional.
- Although the extensive use of bar/Gantt charts are also associated to longer duration projects, the fact that at times they are not used at all does not appear to be associated with the project characteristic "duration".

For the characteristic variable "<u>type of project</u>", only three techniques show a significant association(tables 42-44), namely formal reporting, bar/Gantt charts and milestones on a WBS. One of the major indications of these contingency tables is that the database is to small to comprehensively prove this relationship. The reason for this is that it would be ideal if all the different project types have large equal numbers of data points. What is, however, indicated in the Log-linear tables of Appendix D, is that:

- The extensive use of reporting techniques is more associated with developments/design, construction and general engineering projects
- The extensive use of bar/Gantt charts are associated with construction, implementation and general engineering.
- The extensive use of milestones on a WBS tend to be associated with research, development/design and general engineering projects.

Although the statistical modeling showed these to be three significant results, this was only after quite considerable compression of the data scales and by then reviewing the results. As such, it would possibly be wisest to conclude that in general this trend will remain inconclusive until the survey data is extended.

The last characteristic variable considers the "age" of the project, or number of years ago that the project began. Essentially, the Log-linear tables of Appendix D (tables 23-27) tend to indicate, that:

- There has been a trend in recent times (the last three years) to move away from techniques such as milestones on a WBS, formal meetings and network analysis, although network techniques were not used quite as extensively as the other techniques in the past.
- Computer based applications have in recent times (over approximately the last three years) become more popular.
- The LOB technique has in general only significantly come into use in the last three years. Although this is the indication, it is possible that this relationship is spurious because of the reasons outlined earlier.

It is interesting to note that the only technique which showed no relation to any of the characteristics, was that of "informal meetings". The reason for this is possibly that it was extensively used for all different project characteristics.

A fairly extensive correlation between the techniques chosen and the project characteristics have been shown, although this relationship is stronger for some characteristics than for others. It can, therefore, be concluded that the project practitioners in the South Western Cape, over the last ten years, have either knowingly or unwittingly made the choice of their techniques based to a large extent on the perceived value and duration of the project and possibly also on the type of project.

d. <u>Project Success, Characteristics and Control Techniques</u>

The above three relationships attempted to relate project success, the use of time/schedule control techniques and project characteristics, on a one to one basis. Such relationships would be strictly relevant if there was not a strong interaction affect from another variable. For example, it is quite conceivable that a specific technique may seem unrelated to project success in general, hence showing no one to one relationship. If, however, the same technique were used in projects having specific characteristics, or operating in a specific environment, there may well be a relationship to success in evidence. Knowledge of the existence of such a multi-variate function would provide an improved awareness of the importance of certain structural variables when choosing time/schedule control techniques, as they may influence project success.

The two-way ANOVA results displayed in Appendix C (tables 5-8), show the analysis that was performed in an attempt to determine this multiple relation. In this analysis, the cross product of each of the project characteristics and each of the control techniques were evaluated for functional relationships with the success of the projects. Each table displays the results of the two-way ANOVA for a different characteristic (ie. Age, Type, Value and Duration). The tables in Appendix C indicate those values at which the significance of accepting the null hypothesis (of independence or no relationship) was less than 5%. These Two-Way ANOVA results, however, suffer from the same flaws as the one-way ANOVA results. That is, the analysis procedure is strictly applicable to continuous response variables and there is no indication given of the adequacy of the data in the test.

The preferable option, would have been to perform multi-factor contingency analysis. This would not only have highlighted the relevance of the data for the significant results, but it would also have provided the opportunity of performing Log-linear Modelling in order to determine the <u>form</u> of the relationships. It was, however, not possible to perform the contingency analysis, because it would have involved three dimensional frequency distributions. Such distributions require far more data than has been made available by the industrial survey, in order to produce any reliable results. As such, the trends will have to be interpreted from the two-way ANOVA, bearing in mind the uncertainties.

When considering the two-way ANOVA tables of Appendix C (tables 5-8), there are a number of significant points which should be highlighted:

- In the investigation of one to one relationships between project success and project characteristics, or time/schedule control techniques, the indications of the existance of such relationships were in no way as strong as the general indications of these four tables.

- There are significant indications from table 6 that all of the facets of success (particularly schedule and technical success) are dependent on the choice of a relevant technique to suit the <u>type of project</u> being conducted.
- Table 7 suggests that there are strong indications that the technical success of a project can also be influenced by the choice of time/schedule control techniques, to suit the <u>financial value</u> of the project.
- Table 8 suggests that the financial success of a project (but not its schedule success) can generally be affected by choosing a control technique, to suite the <u>duration of the project</u>. This could mean that the choice of a relevant set of schedule control techniques, for a project having a specific duration, could assist the project manager in meeting his budget goals.
- The indications from Table 5 are interesting in a historical sense, in that they suggest how the project's success has been influenced by the choice of time/schedule control techniques over the last approximately ten years in the South Western Cape. The interpretation here, is that the schedule success attained from the use of certain techniques has not been constant over the years. This could be attributed to the fact that project environmental variables (ie. project manager skills, organisational structuring, management influence and style, contract stipulations, etc.) have been changing over the last ten years. For example, it appears that the schedule success attained from the use of computer based applications has changed over the last ten years. It is, however, not possible to determine from these results whether there has been an improvement or not.

- Although not all the facets of success extensively suggest functional relationships for all techniques, there are techniques which show isolated relationships. For example, the use of "S" curves seem to effect budget success of the project for all characteristics. This could suggest that, when considering the use of such techniques, one should carefully evaluate all project characteristics (ie. project type, value and duration) to determine their suitability.
- Viewing Tables 6 and 7 of Appendix C, it is apparent that when choosing a specific set of schedule control techniques to suit the type and value of the project, not only will either budget or schedule of the project be affected, but also the technical success. This seems to be an odd result, in that it suggests the technical outcome of the project could be influenced by the choice of a suitable time/schedule control procedure. This could, however, be explained by suggesting that the choice of adequate schedule control procedures, which are correctly tailored to suit the project characteristics, will not appear to project participants as being a yardstick against which they are continually being measured. Such techniques could rather be regarded as a meaningful set of tools to pace their work and hence influence the technical success attained on the project.

In conclusion, it appears that there is significant evidence from the two-way ANOVA to suggest that the ultimate success of a project can be influenced by the choice of time/schedule control techniques to suit the characteristics of the project. There are, however, two problems:

a. The credibility of these results can only be verified with a larger database. This will permit the use of contingency analysis which is a more rigorously correct statistical procedure.

b. The <u>form</u> of the relationships can only properly be assessed after such an analysis is conducted. Until such time, the only means for determining this relationship is by assuming that past practice is based to some degree on success and hence considering the historical function "techniques vs characteristic".

5.3 THEORY AND PRACTICE

In the previous two sections of this discussion the major findings, limitations and relevance of the literature and industrial surveys were respectively discussed in some detail. What now remains is to relate the results of the industrial survey, to the findings and theory expressed in literature, and to consider the possibilities for supplementary research work.

In order to meet these objectives, this section is divided into two parts. The first sub-section will illuminate the findings of the literature and industrial surveys, which may prove of practical significance to the practising project manager. The second sub-section briefly points to suggestions for further research in this field of project management.

5.3.1 <u>Practical Applicability of The Findings</u>

This section will summarise those findings of the research, from the literature as well as the industrial survey, which are of practical significance to the practising project manager. It is intended that the findings in the literature and the results of the industrial survey should be viewed in complement. In this way, the research attempts to bring together the theory and practice of time/schedule control of engineering projects.

This investigation has been concerned with three topics in the time/schedule control of projects, namely the control systems, the implication of structural variables and the methods of time/schedule control. As such, their significance will briefly be discussed.

a. **Control Systems**

The first finding of practical significance, concerns an understanding of the place of time/schedule control within a control system and in the management of projects in general. The project manager should understand that of his "planning, leading, organising, controlling and co-ordinating" functions, the action of physically controlling is only one of such management functions. In order to set up and operate a control system, he will be required to use possibly all of these functions. He should realise that the control system consists of not only time/schedule facets, but also cost and quality aspects and that the system is <u>driven by</u>, <u>relies upon</u>, and should be <u>integrated with</u>, an efficient information system.

Control is not a function on its own, it can be viewed as a closed loop system, as illustrated earlier in figure 5.2, and superior control requires accurate <u>planning</u> to form the basis of the control and the start of the control loop. This plan should be detailed enough to facilitate monitoring at the level of control required and not be so elaborate that the project participants are unable to see its value or follow its logic.

This plan only forms the basis against which to control. In the control system loop there is required to be a <u>monitoring</u> function which will form part of an information gathering network. This monitoring function should assess actual progress, in the units appropriate to the work being conducted (ie. man-hours, number of drawings, units completed, etc.), against the plan put forward. It should further be capable of reporting the project progress in a manner which will permit easy evaluation of status of the time/schedule.

To supplement the planning and monitoring functions in a control system, there must be a <u>control action</u>. That is, it will require the "leading, organising and co-ordinating" functions of the project manager, to carry out the control action which maintains project progress within the confines of the project plan. It is this control action which will close the control system loop by continually adjusting progress and re-evaluating the plan itself. This will ensure that the plan remains a meaningful guide to all project participants throughout the life cycle of the project.

b. **Project Characteristics**

The next set of research findings which may prove of use to the practising project manager concern the relation of project characteristics to the success of the project. It should firstly be clear that it is not possible speak about the success of the project in general. It is important to consider the "time, cost and quality" aspects of project success and to remember that a project which is a technical success, may not be a budget or schedule success.

It is important to understand the significance of project <u>structural variables</u> and how these "strategic" factors determine both the <u>characteristics</u> of the project and the <u>environment</u> in which the project finds itself. It would be very convenient for the project manager if either the budget, schedule or technical success of a project could be related to the project characteristics or environment. What this would mean, is that a project manager starting a specific type of project, which had some estimated financial value and duration, would be able to condone schedule and budget overruns and technical failures on the grounds that such poor success is generally related to the specified structural variables.

There are some authors in the literature who would suggest that on "design/development projects of this magnitude, one can expect overruns of budget and schedule". This research, however, found no significant evidence to support such claims. On the contrary, it is suggested here that there are no excuses for bad planning and the poor monitoring and the control actions that are generally associated with it.

c. **Control Methods**

Concerning the type of control methods used, it would not be prudent to list the trends associated with the use of specific techniques in the survey area and suggest that such practices are preferred. Such information basically remains of historical significance. What can, however, be mentioned, is the perceived success of the time/schedule control techniques and the influence of these techniques on the ultimate success of the project.

Once again, it would be convenient for the project manager if it were possible to suggest that the use of particular techniques would lead to significantly improved project success, without any further thought of other influencing factors. Indeed, there are many authors in the literature who have either directly stated or inferred such a relation. In this research, however, there was not a generally significant trend to suggest this. The most logical conclusion to this would be that one cannot rigidly stipulate specific methods for all projects, on the basis of past successes in different situations and on characteristically different projects.

The one relation for which there does seem to be significant statistical evidence, is the association between project characteristic and type of schedule control technique used. In the research area, it was found that project managers were choosing the techniques to control the time/schedule of the project, based to a larger extent on the characteristics of the project (type, financial value and duration) than on the environmental variables (trends discussed in section 5.2.3(a)).

Although this is a historic trend, specific to the survey area, such information is of significance as a first pass, if it can be assumed that this industrial practice is based to some degree on past success. If this is the case, then it is possible to suggest some rough guidelines to the project manager, regarding the use of specific techniques to suit certain project characteristics. These guides include:

- At project financial values less than R1 million, the use of milestones on a WBS, bar/Gantt charts, Network Analysis, "S" Curves and integrated computer planning and control packages, should be carefully evaluated. They should be used occasionally in such circumstances, rather than frequently.
- If the project duration is shorter than one year, the applicability of formal reporting, milestones on a WBS, Network Analysis and "S" Curves should be carefully evaluated and used occasionally rather than extensively.
- The general use of milestones on a WBS, bar/Gantt charts and Network Analysis, on construction, design and development projects may prove of use.
- The use of informal meetings and walking around, to control time/schedule should be used on all projects, rather more than less.

It is also significant that there are some research results to support the supposition that the choice of techniques to suit project characteristics, will influence not only the schedule, but also budget and technical success of the project. It must, however be stressed that the above guides are only estimates, made in the absence of more rigorous statistical evidence (ie. database too small).

With an understanding of the functions of the project manager and how they can be used to form a control system, it is clear that the use of methods such as network analyses or even advanced computer applications, could never replace the entire control system. Such tools are incapable of making the decisions and performing the functions of a project manager, they can only assist in his judgement.

It should also be clear from the systems view that no planner or planning department can rigidly dictate the requirements of a project time/schedule control system to the project participants. It remains the task of the project manager and his team, if not to operate the techniques, at very least to understand their significance and be capable of using the information they generate. As such, the planner or planning department should act in an advisory capacity to the project, by providing objective assistance where required. They should not replace or override the judgements of the project manager and his team.

It should lastly be remembered, that although part of this research has been an attempt to structure the time schedule control procedures for the project manager, it would seem futile to set out rigid prescriptions. What must be remembered is that the time/schedule control of a project is a dynamic management function and will always rely heavily on the intuitive management skills of the project manager when negotiating his project through the working environment of the real world. All this research can achieve, is to highlight some of the common fallacies associated to time/schedule control and to provide some guides to the project manager that may assist in his management functions.

5.3.2 Future Investigations

The scope of this research has been particularly broad, in that one of its objectives has been to piece together the largely fragmented theoretical background on time/schedule control of projects and to place this into perspective in terms of project management in general.

Due to the fact that the research was so broad based, one of its major accomplishments is that it has opened a series of avenues for continued investigation in the field of project management. The following is a short summary of some of the possibilities that have become apparent.

a. The multi-variate relation between project success, project characteristics, and control techniques used, were inconclusive. The reason is that the number of projects obtained from the survey was insufficient to perform the required statistical procedure. If the research data could be extended, it would not only be possible to come to a firmer conclusion regarding the existance of this function, but it may also be possible to determine the form of this relationship. That is, it may be possible to determine which techniques are most suitable for different project characteristics and will hence positively influence project success.

b. Models have been put forward to describe the place of project control within project management and to describe the operation of a control system, using the literature survey and logical deduction. It was not possible to verify these models or to ascertain their applicability to current practice, with the use of a mailed questionnaire survey. Such practices can only fully be investigated by a more detailed industrial survey which concentrates in depth on the systems adopted by a few select organisations, or a series of select projects.

c. The industrial survey of this research divided the structural variables, associated with the make-up of the project, into two categories (characteristic and environmental). It then investigated the effect which four of the characteristic variables would have. The characteristic "complexity" was excluded due to the subjectivity its response would likely deliver, while certain environmental variables were fixed (industrial/engineering projects of the South Western Cape) and the others were ignored due to the enormous number that could be considered. The relevance of these decisions, it was felt, were justified for the detail of this research. It would, however, be of interest to investigate the influence of some of the environmental variables in more detailed studies, possibly by fixing certain of the characteristic variables.

6. CONCLUSIONS

6.1 The literature on project control is both wide ranging and extremely fragmented. In order to piece together a cohesive mass of theory on the topic, the information can be categorised into three interrelated bodies, namely the control systems view, the structural factors view and the control methods view.

6.2 The basis of each of these categories can be described as follows:

a. The systems view concerns; the place of time/schedule control in project control systems, the place of control in project management in general, and how the project management functions can be used to support such control.

b. The structural variables of the project are those strategic factors which determine the characteristics of the project and the environment in which the project operates. As such, these variables influence the operation of the control system and the ultimate success of the project.

c. There are a vast array of methods, techniques and heuristics which can be used as tools to form either the planning or monitoring functions within a control system. They differ in purpose and degree of complexity, and the choice of a suitable combination of these will impact on the project manager's ability to interpret the information coming from the monitoring function of the control system. This will in turn influence his control action and the ultimate success of the project.

6.3 From the analysis of the industrial survey questionnaire, the following is evident:

a. The methods referred to in the literature, and understood in industry to be control techniques, are either planning or monitoring methods. The control actions are executed by the project manager and his team, by making use of the information generated by the planning and monitoring methods used.

b. There appears to be no meaningful support for the inference that projects, having specific characteristics, can be expected to be either successful or unsuccessful because of those characteristics alone.
c. There appears to be no practical support for the notion suggesting that the use of specific techniques will intrinsically guarantee improved success.
d. There is some statistical evidence to suggest that the ultimate success of a project (ie. its budget, schedule, or technical success) can be influenced by the choice of control techniques to suit project characteristics. It is, however, uncertain what this multi-factor relation is, due to the fact that the research database was too small. At best rough guides can be given as to the form, until the database is enlarged.
e. It is unwise to make rigid prescriptions to the project manager about the techniques he must use on all of his projects, as the above multi-factor relationships may further be influenced by a multitude of environmental variables.
f. When choosing a suitable set of control techniques, the decision remains one which relies to a large extent on the intuition of the project manager. He should bear in mind his understanding of the techniques available, and the characteristic and environmental factors influencing such a decision.
g. There is support for the use of a planning engineer to act as an objective guide to the project manager and his team. The planning engineer would aid in the selection, setting-up and possible operation of techniques for the control system.

6.4 Because the industrial survey was targeted at engineering/industrial concerns in the South Western Cape, there are a number of conclusions that can be made about the control of time/schedule on such projects.

a. There is evidence to suggest that practitioners in the survey were basing their choice of techniques, for project control information, on the characteristics of the project. This suggests that the division of a project's structural attributes into "charcteristic" and "environmental" variables, is a valid one.

b. The extent of use of the different methods of time/schedule control have been changing over the last ten years. Most notably, there seems to be a decline in the use of network procedures, formal meetings and milestones on a work breakdown structure, while simultaneously an increase in the use of computer applications.

c. The research data suggests that it is the simpler time/schedule control methods which are mostly used. There does not appear to be an extensive understanding or use of the more sophisticated tools such as networks, line of balance, "S" curves and computer applications.

6.5 Although some of the results of the survey appear to provide fairly conclusive evidence to support these conclusions, there are reasons to advise caution in viewing the results. Such reasons are largely due to limitations in the method adopted during the industrial survey. They include a research database which is too small to adequately show the form of the multi-variate function, the fact that a questionnaire type survey does not permit a detailed study of the control systems used in practice, and that there remain uncertainties as regards possible self-bias and representativeness of the survey, to name but a few.

6.6 The majority of the original objectives, set up at the outset of the research, have been met, with a few exceptions. In general the achievements can be summarised as:

a. The research has been able to place the fragmented literature into some perspective in terms, of time/schedule control of projects.

b. It has highlighted the significance of the relationship between the ultimate success of the project, the structural variables and the choice of time/schedule control methods. A larger database would be required to more rigorously determine the form of this relationship.

c. It has been possible to set out some broad guidelines to the practising project manager, who wishes to know what should be done in order to effectively control time/schedule (See recommendations in next section).
d. The industrial survey has provided some indication of the practices adopted for the time/schedule control in "real world" projects of the South Western Cape.
e. The broad-based scope of the research has highlighted a number of significant areas for extensions to this research. There are also several possibilities for new research topics by modifying procedures or variables adopted in this research (Detailed in the Recommendations).

7. RECOMMENDATIONS

The recommendations of this research will be divided into two parts. The first part consists of some guidelines to the practising project manager. The second part suggests the possibility for further research in the field of project time/schedule control.

7.1 PRACTICAL GUIDELINES

The recommendations to practising project managers take the form of a set of rough guidelines. The reason for this is because the research has concluded that it is "unwise to make rigid prescriptions to a project manager on time/schedule control methods". The guidelines include the following:

a. He should be aware that control is only one of his management responsibilities and that time/schedule control is only one facet of this control.
b. He should be aware that he controls the project through a <u>control system</u>, in which there are elements of <u>planning</u>, <u>monitoring</u> and <u>control action</u>. The plan forms the baseline against which to control, while the monitoring function checks actual performance against the plan and requires accurate information. The control action operates within the control system to maintain acceptable actual time/schedule control performance.
c. He should be aware that the use of computers and such techniques as networks, LOB, reporting and others are merely tools at his disposal, to assist the planning and monitoring of a project. Such tools are not synonymous with project management, they do not control and cannot replace his intuitive management skills, they can only aid him in his decision making.
d. He should be aware that no single technique, or group of techniques, will provide him with guaranteed success on all projects.

e. He should understand that it is unlikely that the characteristics of a project (its type, value or duration), determine success alone.

f. He should be aware that the success of the techniques used to control time/schedule, as well as the ultimate success of the project, are dependant on the selection of the techniques to suit at least the characteristics of the project. This success is possibly also dependent on the environment in which the project finds itself. Some indications of what this relationship may be, include:

   - At project financial values less than R1 million, the use of milestones on a Work Breakdown Structure (WBS), bar/Gantt charts, Network analysis, "S" curves and integrated computer planning and control packages, should be carefully evaluated. They should be used occasionally in such circumstances, rather than frequently.
   - If the project duration is shorter than one year, the applicability of Formal reporting, milestones on a WBS, Network analysis and "S" curves should be carefully evaluated and used occasionally rather than extensively.
   - The general use of milestones on a WBS, bar/Gantt charts and Network analysis, on construction, design and development projects may prove successful.
   - The use of informal meetings and walking around, to control time/schedule should be used on all projects, rather more than less.

g. The use of a planning engineer to aid the project manager and his team in choosing, setting up and operating the time/schedule control techniques, could be beneficial to the project, provided the size of the project can justify the expense of such a person. If a planner <u>is</u> used, his input should provide guidance to the needs of the project manager and his team. This input should not override the project managers judgements, or be based on the planner's input alone.

7.2 SUPPLIMENTRY RESEARCH

It is recommended that the research into <u>this</u> area of project management be continued, as this research has highlighted areas for further investigation. These areas include the following:

a. The database obtained from the questionnaire should be expanded, possibly over a larger geographic area, in order that the significance and form of the multi-variate relationship between success, characteristics and techniques, can be more reliably determined.

b. A survey of narrower but deeper scope should be conducted. It should make more extensive use of personal interviews, in order to establish the validity of the illustrated model of a project control system.

c. It should be investigated to what extent environmental variables, as opposed to characteristic variables, affect the choice of technique and ultimate success of the project.

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APPENDIX A

THE INDUSTRIAL SURVEY

UNIVERSITY OF CAPE TOWN

Department of Mechanical Engineering

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Telephone: (021) 650-3229; Telex: 521439SA
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Head of Department: Assoc. Prof. K F Bennett

24 August 1989

Dear Sir

As part of the ongoing research of the University of Cape Town, the Faculty of Engineering is investigating the use of project management techniques in our local industrial environment. This follows a survey from which it became apparent that this field of engineering management caused the greatest concern to many companies.

The University intends to create a centre of expertise in project management matters for the benefit of local industry. In order for our post-graduate students to validate their theoretical research, we are in need of real world information and as such would greatly appreciate your co-operation in completing the attached questionnaire.

As the information we are seeking is important to the study, and as it is desirable to obtain as many samples as possible, we will guarantee confidentiality of any information with which we are provided. Should you feel you know of someone else, possibly in your organisation, who could also contribute to this survey, it would be appreciated if you would either pass the questionnaire on or reproduce it for them.

We would like to begin processing the information by late September and look forward to a reply at your earliest convenience. Enclosed is a stamped self-addressed envelope for returning the completed questionnaire.

Thanking you for your co-operation.

Yours faithfully

signature removed

Gordon Lister
Senior Lecturer

GUIDELINES FOR COMPLETING THIS QUESTIONNAIRE

1. It is recommended that the person completing this questionnaire have knowledge of the procedures adopted by his/her organisation for appraising a project and/or for planning and controlling time within a project.

2. In order to complete the questionnaire it is required that a range of up to 5 specific industrial projects conducted in the South Western Cape, within the past 10 years, receive focus. (If 5 suitable projects have not been conducted, focus on as many as you can.)

3. It is also recommended that the entire questionnaire be answered for one project at a time. (i.e. Complete the entire questionnaire with respect to one project and then repeat the procedure for any subsequent projects chosen.)

4. Should it not be possible to complete some questions, please do not refrain from completing the rest of the questionnaire and returning it.

5. Should you require clarity on any aspect of this questionnaire please contact either

Antony Möller	PH 938 3094	(WORK)
	PH 797 8422	(AH)

or

Ian Möller	PH 87 3551	(WORK)
	PH 797 4621	(AH)

SURVEY ON PROJECT APPRAISAL AND CONTROL

Considering a range of anything up to 5 engineering projects that have been completed in the last approximately 10 years, answer each of the following questions for each project, by placing a number in the block under the appropriate project column.

PROJECT NUMBER

1	2	3	4	5

GENERAL

1. Estimate the number of years ago that each of your selected projects began.

2. Which category below most aptly describes the type of project under consideration in each case? (A project may involve more than one category. Choose the number of the one which most closely describes it.)

   [1] Research project. (Development of a new concept).

   [2] Development/Design project. (Concept already developed. Details of the particular application to be finalised.)

   [3] Construction project. (Building/manufacture of a "one off" design concept).

   [4] Commissioning. (Bringing a system into operation).

   [5] Implementation project. (The construction and commissioning of an industrial process).

   [6] General engineering project (Contains elements of feasibility study, design, construction/manufacture and commissioning with no particular emphasis being placed on any one element).

   [7] Other (specify)..

3. Within which one of the following cost ranges does each of your chosen projects fall?

   [1] R0 - R10 000

   [2] R10 000 - R100 000

   [3] R100 000 - R1 MILLION

   [4] R1 MILLION - R5 MILLION

   [5] > R5 MILLION

4. Into which of the following duration categories do each of the chosen projects fall?

   [1] 0 - 6 MONTHS

   [2] 6 MONTHS - 1 YEAR

   [3] 1 YEAR - 3 YEARS

   [4] 3 YEARS - 5 YEARS

   [5] > 5 YEARS

PROJECT PLANNING AND CONTROL

5. Apply the scale:-

[1] Not used at all [2] Used on occasions [3] Used extensively

to rate the use of each of the following in controlling time schedule for each of the projects considered.

	1	2	3	4	5
(a) Informal meetings and "walking around"					
(b) Formal general meetings					
(c) Regular, formalised reporting					
(d) Bar/Gantt charts indicating work durations and % completion					
(e) Milestones on a work breakdown structure					
(f) PERT/CPM network					
(g) Line of balance					
(h) Progress "S" curves					
(i) An integrated computer-based planning & control package					
(j) Other (specify)...					

6. Using the following scale :

[1] True [2] False

indicate for your chosen projects whether or not each of the following statements apply to the schedule control techniques you used.

The techniques used were :

	1	2	3	4	5
(a) so complex that project participants struggled to understand them.					
(b) too simple to be an adequate guide for time-schedule control.					
(c) so powerful they were generally regarded as being "over-kill" for the project.					
(d) specially adapted to meet our specific requirements on the project.					
(e) widely accepted by project participants as being meaningful.					
(f) structured so that they required minimal effort to institute.					
(g) structured so that they required minimal effort to keep up to date.					
(h) generally regarded as achieving the required level of schedule control.					
(i) integrated with project cost and quality control mechanisms.					
(j) applied throughout the full duration of the project.					
(k) Other (specify)...					

1	2	3	4	5

7. Who would you say is responsible for the planning of the time-schedule control techniques identified in question 5.

   [1] Project manager

   [2] Planning engineer

   [3] Planning department

   [4] Financial department

   [5] An administrative department or person

   [6] Other (specify)..

8. Use the scale:-

   [1] No influence   [2] Slight influence   [3] Strong influence

   To indicate how strongly each of the following (a - g) affect the choice of time-schedule control technique used to control the projects you have identified?

   (a) Project complexity

   (b) Project type

   (c) Project size

   (d) Management influence

   (e) Intuitive judgement

   (f) Client's contract

   (g) Other (Specify)..

PROJECT APPRAISAL

9. Using the scale : [1] None [2] Brief [3] Average [4] Thorough

   rate the consideration given to each of the following studies (a - c) when appraising the viability of each project.

   (a) Technical feasibility study (i.e. what technical considerations must be allowed for in order to successfully complete the project?).

   (b) Operational suitability study (i.e. will the completed project meet required operating specifications?).

   (c) Financial viability study (i.e. how expensive/profitable will the project be?).

1	2	3	4	5

10. Using the scale:-

[1] Was considered first

[2] Was considered second

[3] Was considered third

state the chronological order in which each of the studies given below was considered for each project. Should any of the studies not have been considered at all, leave the relevant space blank.

(a) Technical feasibility study e.g. 2

(b) Operational suitability study 1

(c) Financial viability study 3

11. Using the notation: [1] Yes [2] No

state whether or not any formal techniques were used to appraise either the <u>technical feasibility</u> or the <u>operational suitability</u> of your chosen projects.

12. If your answer to the above question was "<u>yes</u>" for any of your chosen projects, please state the techniques used in the spaces provided below and show to which projects they apply by using the notation:

[1] Used [2] Not used

in the blocks provided for each project.

<u>Technical feasibility</u>

(a) ....

(b) ....

<u>Operational suitability</u>

(a) ....

(b) ....

1	2	3	4	5

13. Using the notation : [1] Used [2] Not used

decide whether or not each of the following categories of techniques were used to assess the <u>financial</u> viability of each of your chosen projects

<u>CATEGORIES</u>	<u>EXAMPLES OF TECHNIQUES</u>
(a) Subjective techniques	gut feel/intuitive preference
(b) simple summation techniques	Trading profit
(c) simple ratio techniques	Return on investment Return on capital employed Return on sales income Payback time
(d) summation techniques using discount rate	Net present value
(e) ratio techniques using discount rate	Internal rate of return Overall rate of return Present value index
(f) Techniques involving sensitivity analysis	Monte Carlo simulation Re-iteration of the NPV technique for discrete variations of each project
(g) Other (specify)..	

14. Using the scale: [1] None

[2] Below average

[3] Average

[4] Above average

[5] Extremely high

rate the contribution made by each of the following disciplines in your organisation, in appraising each project. (NOTE: contributions by top management can be broken down into the backgrounds of the personnel at that level.)

(a) Marketing

(b) Accounting

(c) Administration

(d) Engineering / Technical

(e) Project Management

(f) Other (specify) ....

PROJECT PERFORMANCE

15. Using the following scale as a measure of project performance;

[1] Exceeded all expectations

[2] Exceeded some expectations

[3] Met most expectations

[4] Could not meet some expectations

[5] Could not meet any expectations

how successful would you say each project was in terms of;

(a) Meeting budget costs

(b) Meeting time schedule

(c) Meeting technical requirements

	1	2	3	4	5
(a)					
(b)					
(c)					

****

- Please note that this questionnaire may remain anonymous should you so wish.
- If, however, you are able to supply your name and the name of the organisation in which you are currently employed, please do so in the space below. This information will still remain confidential but will enable us to correlate industrial trends.

  Your Name: ....

  Organisation Name: ....

- If you would be available for a short interview (should it prove necessary), could you please supply your telephone number in order for us to arrange a meeting at your convenience.

  Tel Number: ....

APPENDIX B

THE SURVEY DATA AND RESULTS

SURVEY QUESTION NUMBERS

Proj No.	1	2	3	4	5a	5b	5c	5d	5e	5f	5g	5h	5i	5j	6a	6b	6c	6d	6e	6f	6g	6h	6i	6j	6k	8a	8b	8c	8d	8e	8f	8g	15a	15b	15c
1	2	6	5	3	2	3	3	3	3	3	3	3	3		1	2	2	1	1	1	1	1	2	1		3	1	3	3	1	1		2	4	1
2	4	3	4	2	2	3	3	3	2	1	1	1	1		2	2	2	1	1	1	1	1	1	1		3	2	3	2	2	3		2	4	3
3	5	3	4	1	1	3	3	3	3	1	1	1	1		2	2	2	1	1	1	1	1	2	1		2	2	3	3	2	3		4	4	3
4	5	3	3	1	2	2	2	2	1	1	1	1	1		2	2	2	1	1	1	1	1	2	1		3	3	2	3	3	3		3	4	3
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7	3	2	3	3	2	3	3	3	1	1	2	1	1		2	1	2	1	1	1	1	1	2	1		3	3	3	1	2	3		3	2	3
8	3	2	3	3	2	3	3	3	1	1	2	1	1		2	1	2	1	1	1	1	1	2	1		3	3	3	1	2	3		3	2	3
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21	7	5	3	2	2	2	2	2	2	2	1	2	1		2	1	2	1	1	1	1	1	1	1		2	3	1	1	2	3		4	3	4
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26	7	3	5	4	1	3	3	3	3	3	1	3	3		2	2	2	1	2	2	2	1	1	1		3	3	3	3	2	1		3	3	3
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SURVEY QUESTION NUMBERS

Proj No.	1	2	3	4	5a	5b	5c	5d	5e	5f	5g	5h	5i	5j	6a	6b	6c	6d	6e	6f	6g	6h	6i	6j	6k	8a	8b	8c	8d	8e	8f	8g	15a	15b	15c
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73	5	6	5	5	2	3	3	2	1	3	1	3	3		2	2	2	1	1	1	1	1	2	2	1	3	2	3	2	3	1		5	5	2
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86	8	6	5	3	3	3	3	3	3	3	1	3	3		2	2	2	1	1	1	1	1	2	1		3	3	3	2	1	1		3	2	3
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88	5	6	5	5	3	3	3	3	3	3	1	3	3		2	2	2	2	1	2	1	1	1	1		3	3	3	2	1	1		3	3	3
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92	2	6	1	3	3	2	2	3	2	3	2	2	3		1	2	1	2	1	1	2	2	2	2		2	2	2	1	3	2		3	3	4
93	2	6	1	4	3	2	2	3	2	3	2	2	3		1	2	1	2	1	1	2	2	2	2		2	2	2	1	3	3		4	3	3
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96	1	6	2	1	2	3	1	2	3	1	1	1	1		2	2	2	1	1	1	1	1	2	1		3	2	3	1	2	1		2	4	2
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99	3	1	5	3	3	3	3	3	3	1	1	1	1		2	2	2	2	1	1	1	1	1	1		3	3	3	3	2	1		3	3	3
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101	9	3	2	1	3	3	3	3	2	2	2	1	1		2	2	2	1	1	1	1	1	1	1		3	3	3	2	2	2		3	3	3
102	0.5	3	2	1	3	3	3	3	2	2	2	1	1		2	2	2	1	1	1	1	1	1	1		3	3	3	2	2	2		3	3	3
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Proj No.	SURVEY QUESTION NUMBERS																																		
	1	2	3	4	5a	5b	5c	5d	5e	5f	5g	5h	5i	5j	6a	6b	6c	6d	6e	6f	6g	6h	6i	6j	6k	8a	8b	8c	8d	8e	8f	8g	15a	15b	15c
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127	1	3	5	3	3	2	2	3	2	2	3	3	3		2	2	2	1	1	1	1	1	1	1		3	3	2	2	2	1		1	3	2
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SURVEY QUESTION NUMBERS

Proj No.	1	2	3	4	5a	5b	5c	5d	5e	5f	5g	5h	5i	5j	6a	6b	6c	6d	6e	6f	6g	6h	6i	6j	6k	8a	8b	8c	8d	8e	8f	8g	15a	15b	15c
167	5	6	5	4	3	3	3	3	3	1	1	3	1		2	2	2	1	1	1	1	2	2	1		3	2	3	2	2	2		3	3	3
168	3	3	2	1	2	3	1	3	1	1	1	1	1		2	2	2	1	1	1	1	1	2	2		3	2	3	2	2	2		2	2	3
169	4	3	3	3	2	3	3	3	1	1	1	3	1		2	2	2	1	1	1	1	1	2	1		3	2	3	2	2	2		2	4	3
171	1	6	2	1	3	2	1	1	1	1	1	1	1													2	2	2	2	3	1		3	3	3
172	1	2	3	1	3	2	1	1	1	1	1	1	1													2	2	2	2	3	1		3	3	3
173	1	3	3	1	3	2	2	2	2	2	1	1	2													2	2	2	2	3	3		3	3	3
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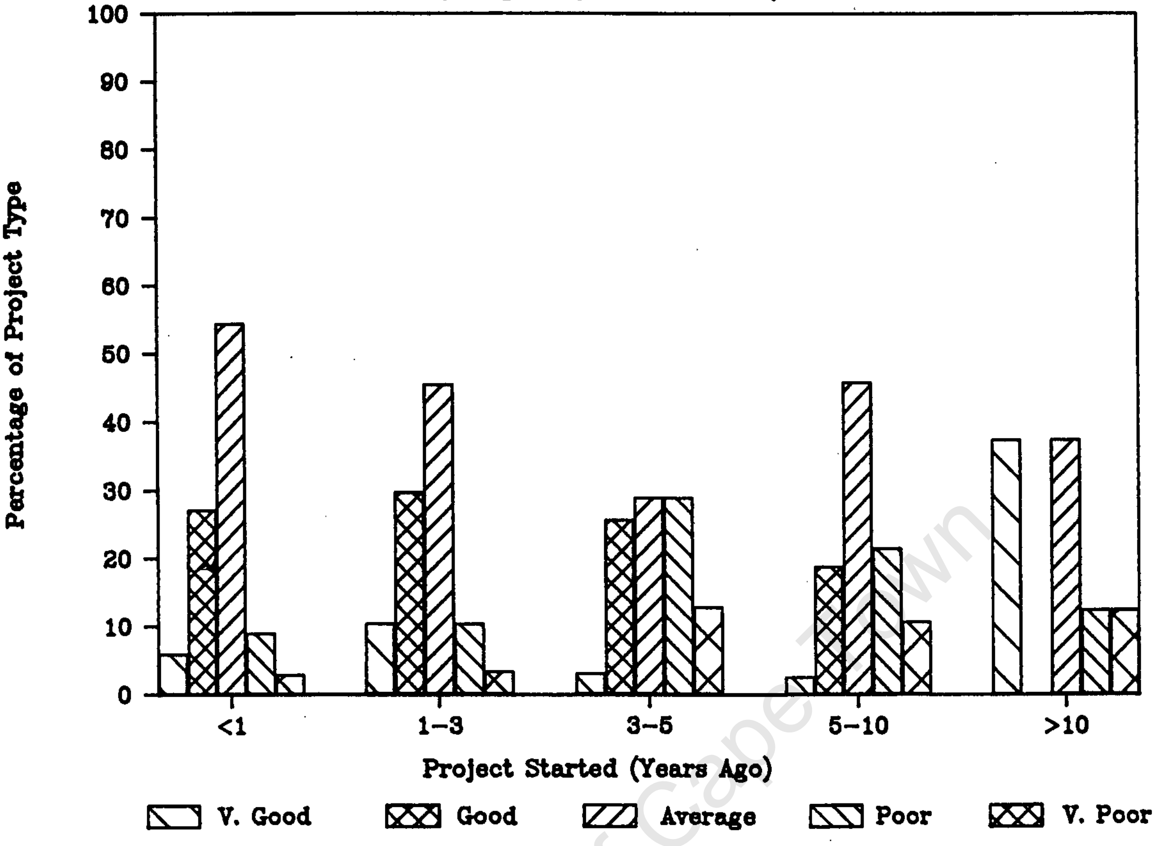
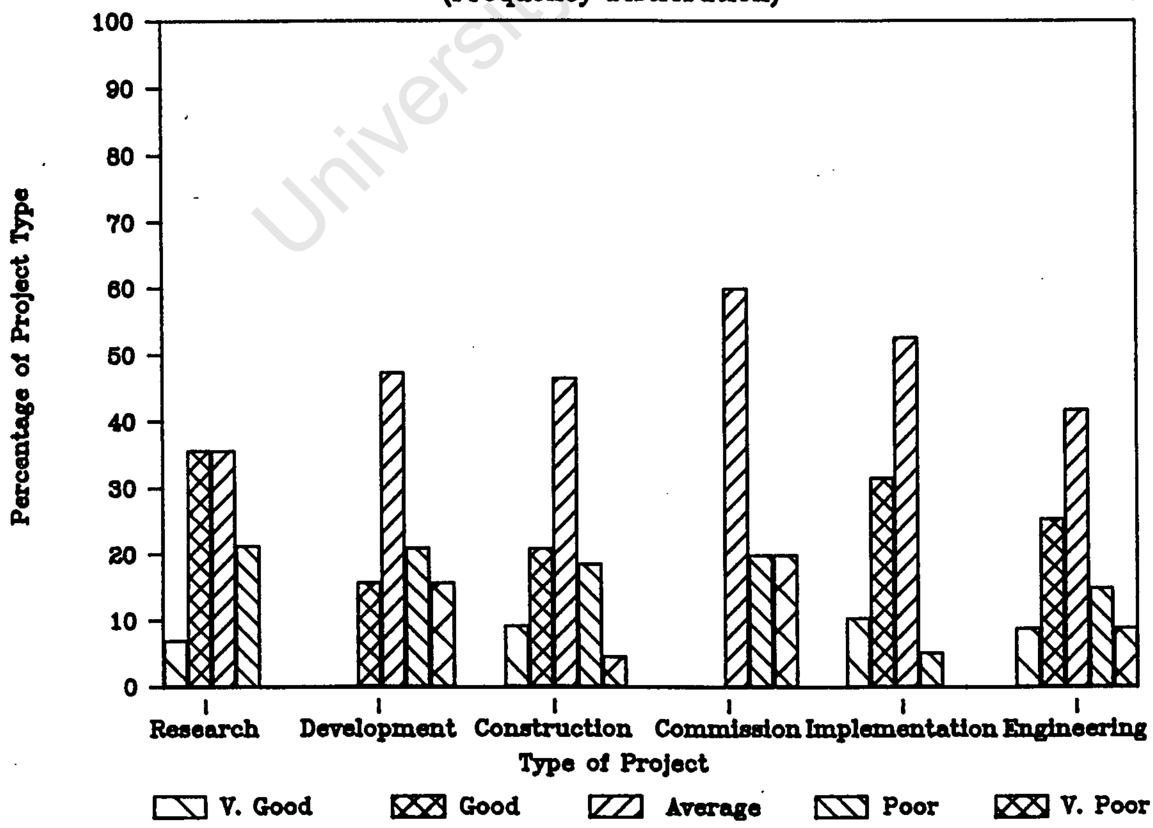
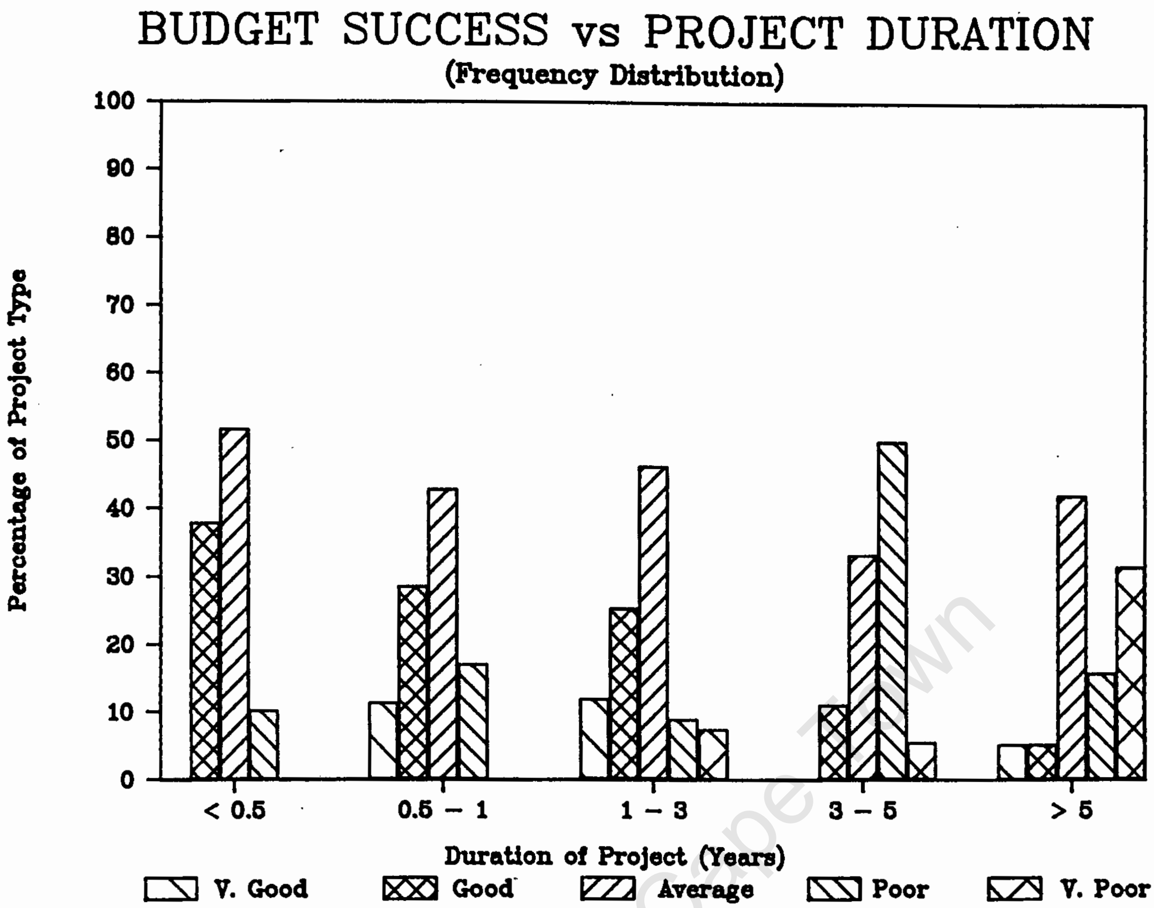
175	1	3	2	1	3	2	1	1	1	1	1	1	1		2	2	2	1	1	1	1	1	1	1		1	3	3	1	2	1		3	3	2

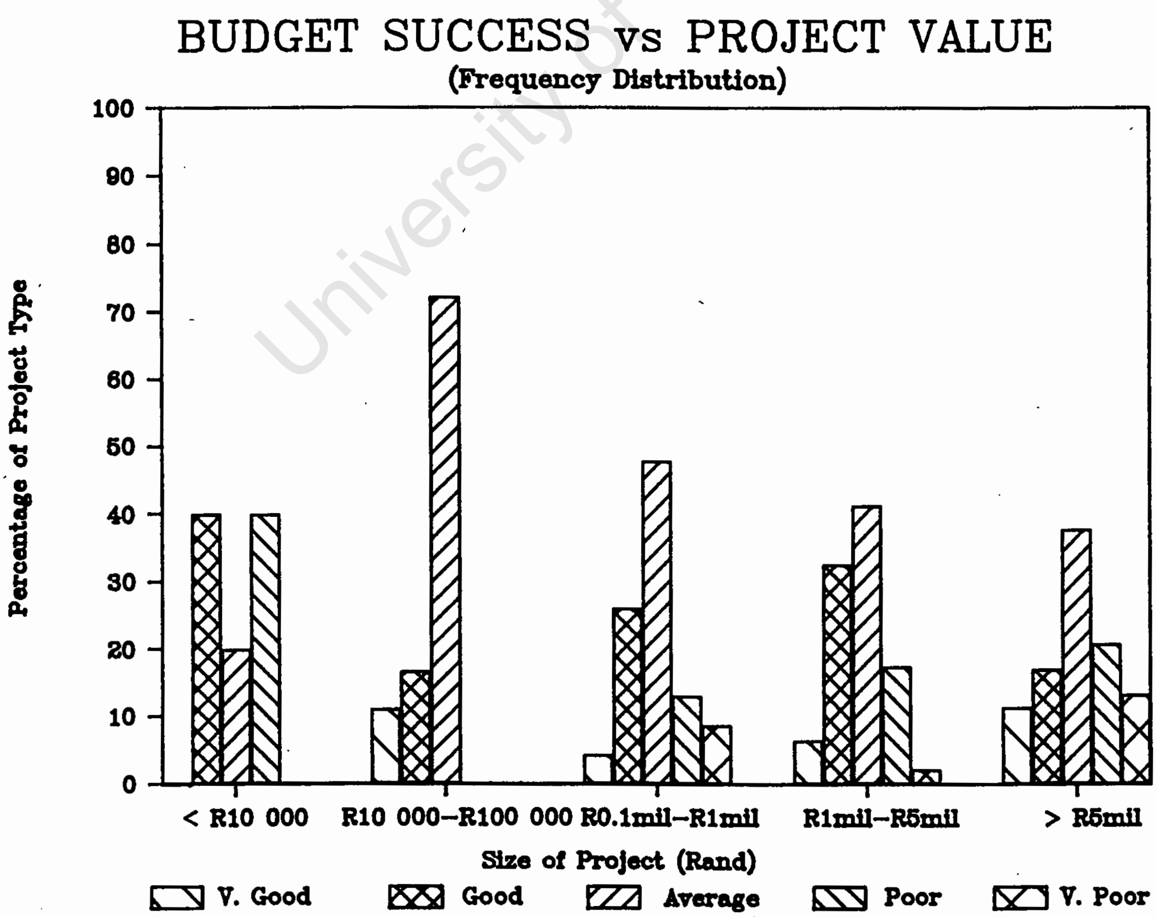
BUDGET SUCCESS vs PROJECT AGE
(Frequency Distribution)



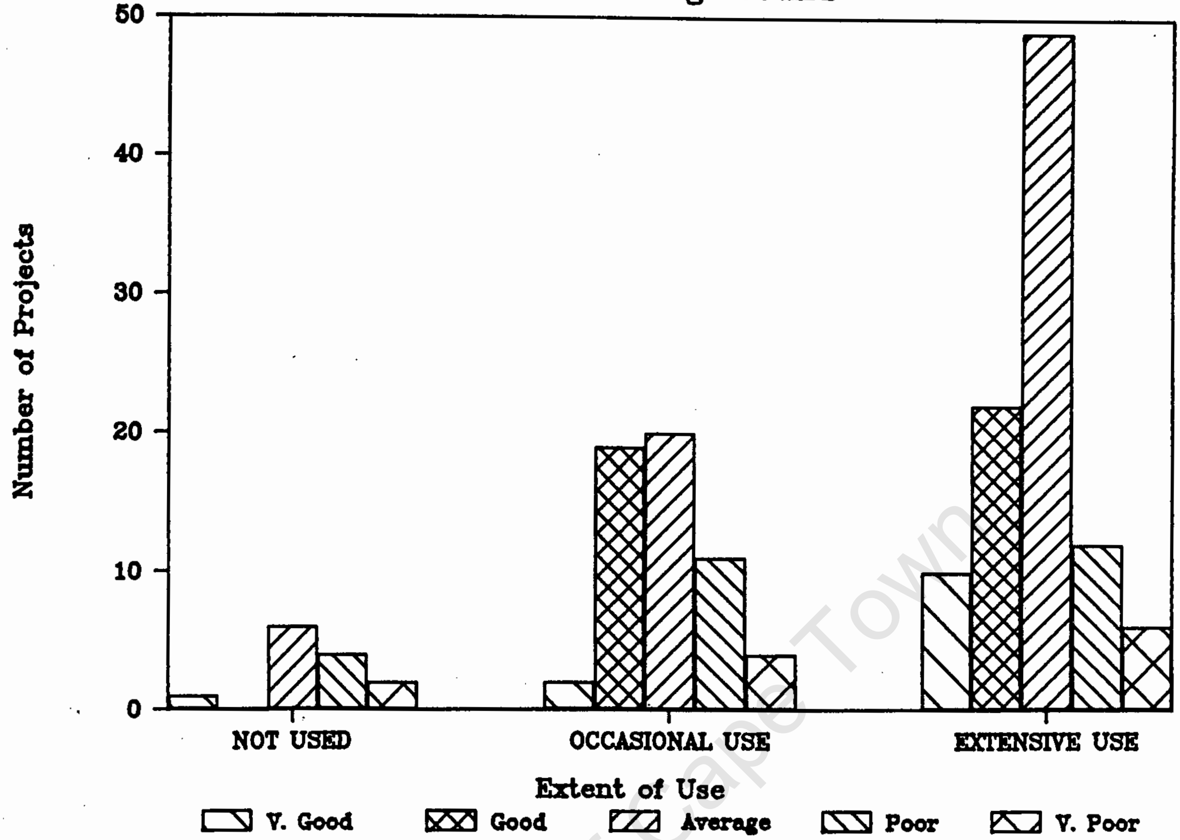
BUDGET SUCCESS OF PROJECT TYPES
(Frequency Distribution)



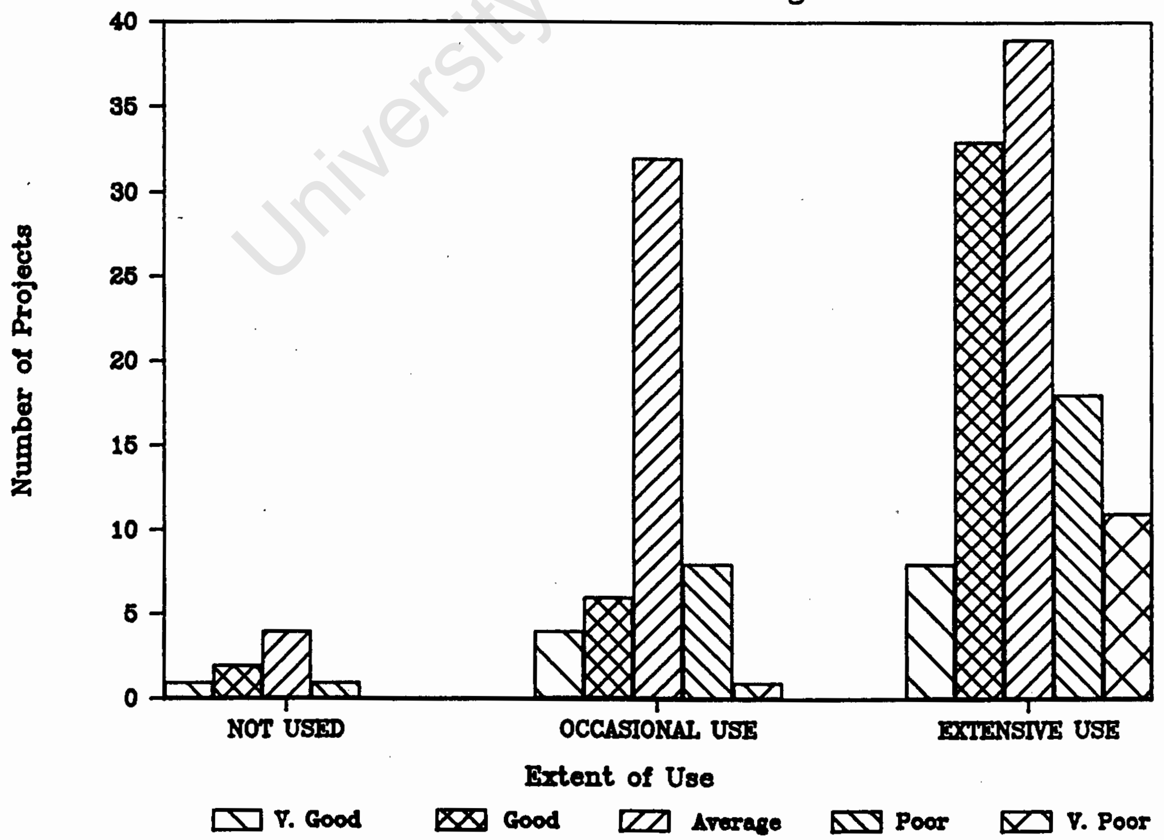

BUDGET SUCCESS vs PROJECT DURATION
(Frequency Distribution)
Percentage of Project Type
100
90
80
70
60
50
40
30
20
10
0
< 0.5
0.5 – 1
1 – 3
3 – 5
> 5
Duration of Project (Years)
V. Good
Good
Average
Poor
V. Poor


BUDGET SUCCESS vs PROJECT VALUE
(Frequency Distribution)
Percentage of Project Type
100
90
80
70
60
50
40
30
20
10
0
< R10 000
R10 000–R100 000
R0.1mil–R1mil
R1mil–R5mil
> R5mil
Size of Project (Rand)
V. Good
Good
Average
Poor
V. Poor

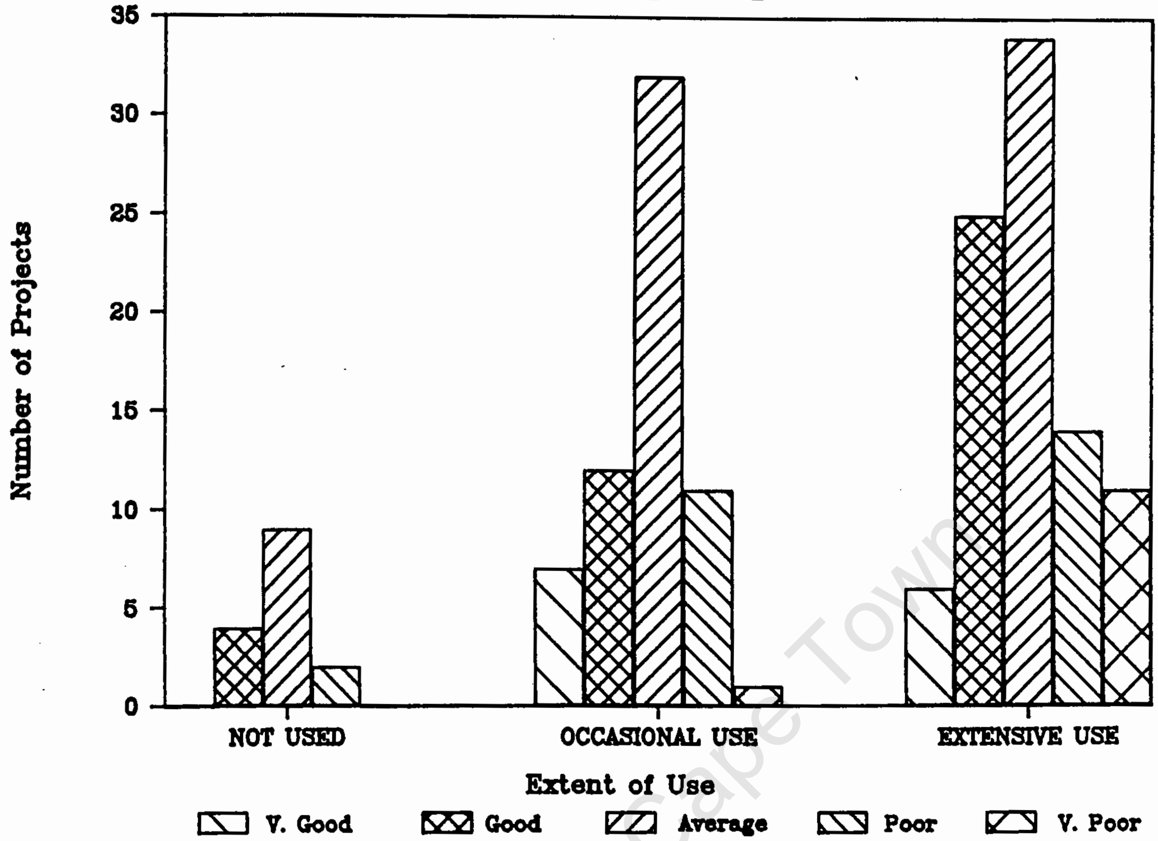
BUDGET SUCCESS vs CONTROL TECHNIQUE
Informal Walking Around



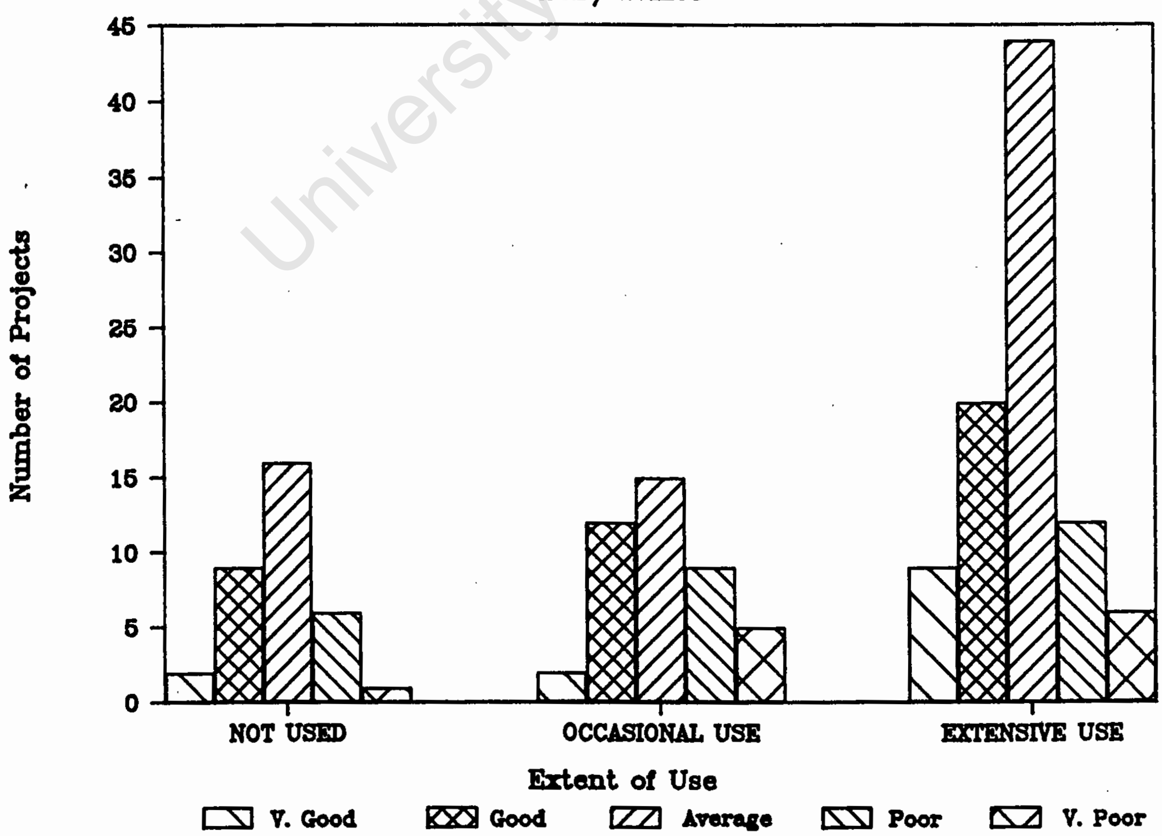
BUDGET SUCCESS vs CONTROL TECHNIQUE
Formal General Meetings

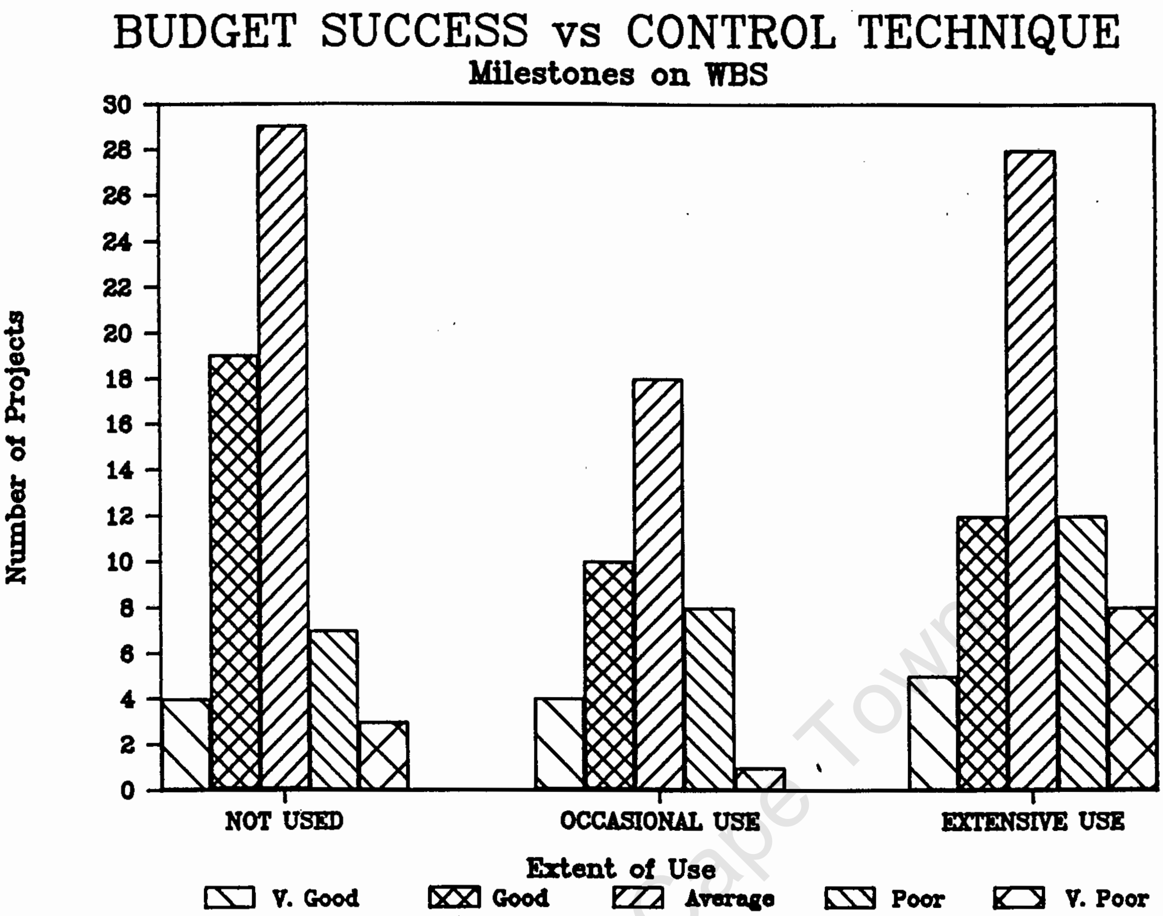


BUDGET SUCCESS vs CONTROL TECHNIQUE
Formal Reporting

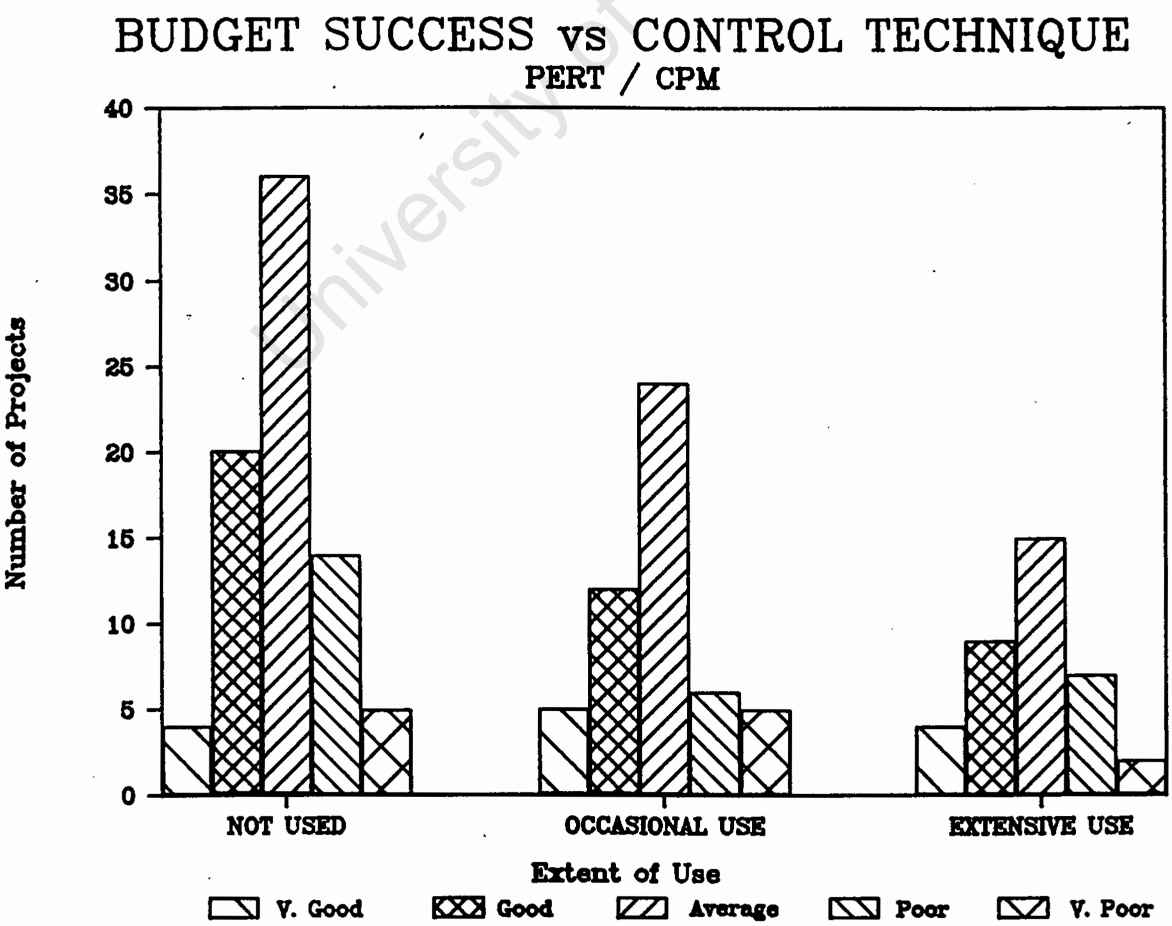


BUDGET SUCCESS vs CONTROL TECHNIQUE
Bar/Gantt





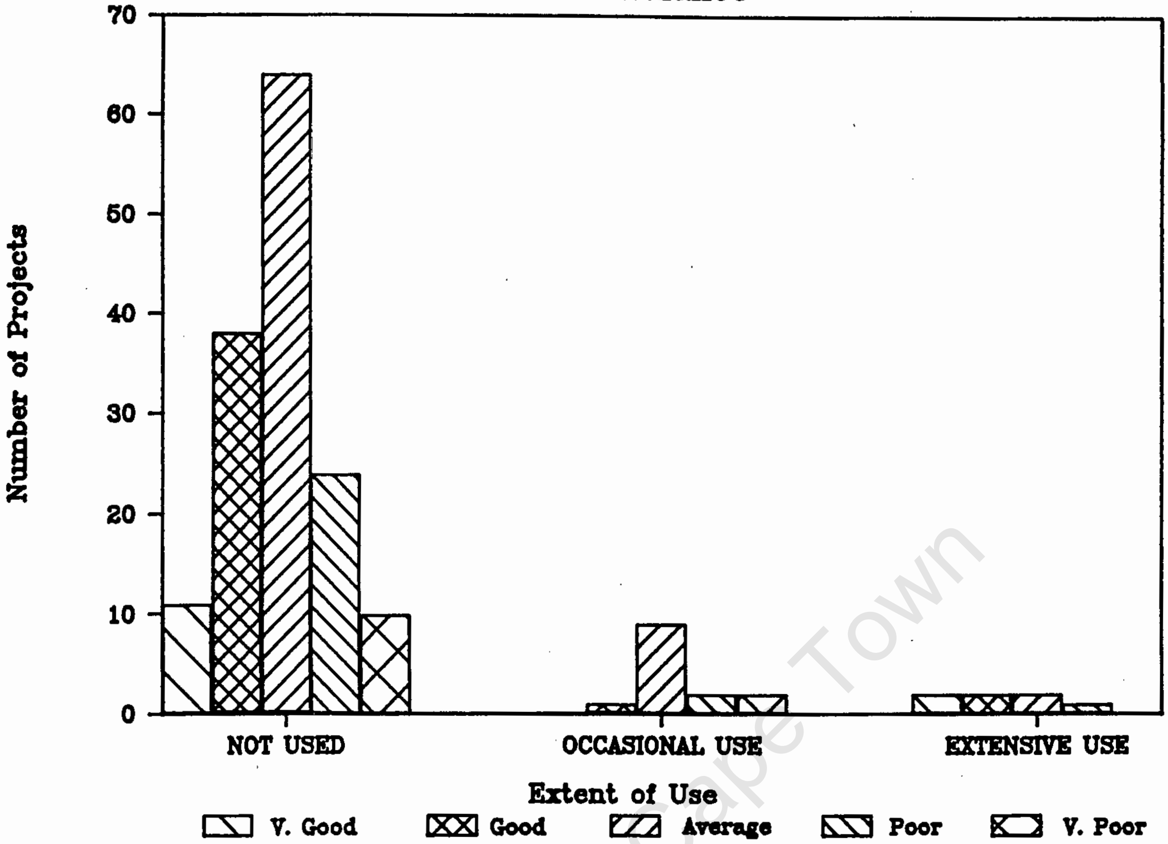
BUDGET SUCCESS vs CONTROL TECHNIQUE
Milestones on WBS
Number of Projects
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor



BUDGET SUCCESS vs CONTROL TECHNIQUE
PERT / CPM
Number of Projects
0
5
10
15
20
25
30
35
40
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

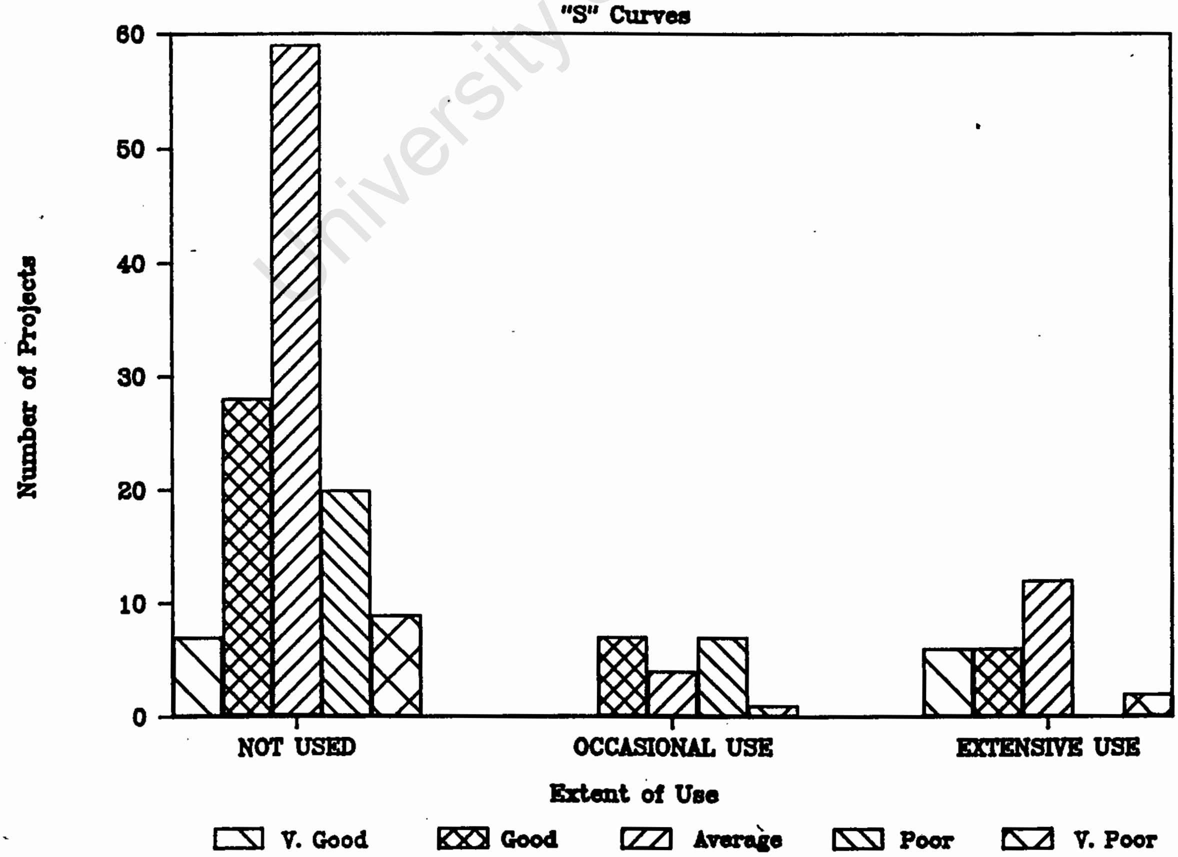
BUDGET SUCCESS vs CONTROL TECHNIQUE

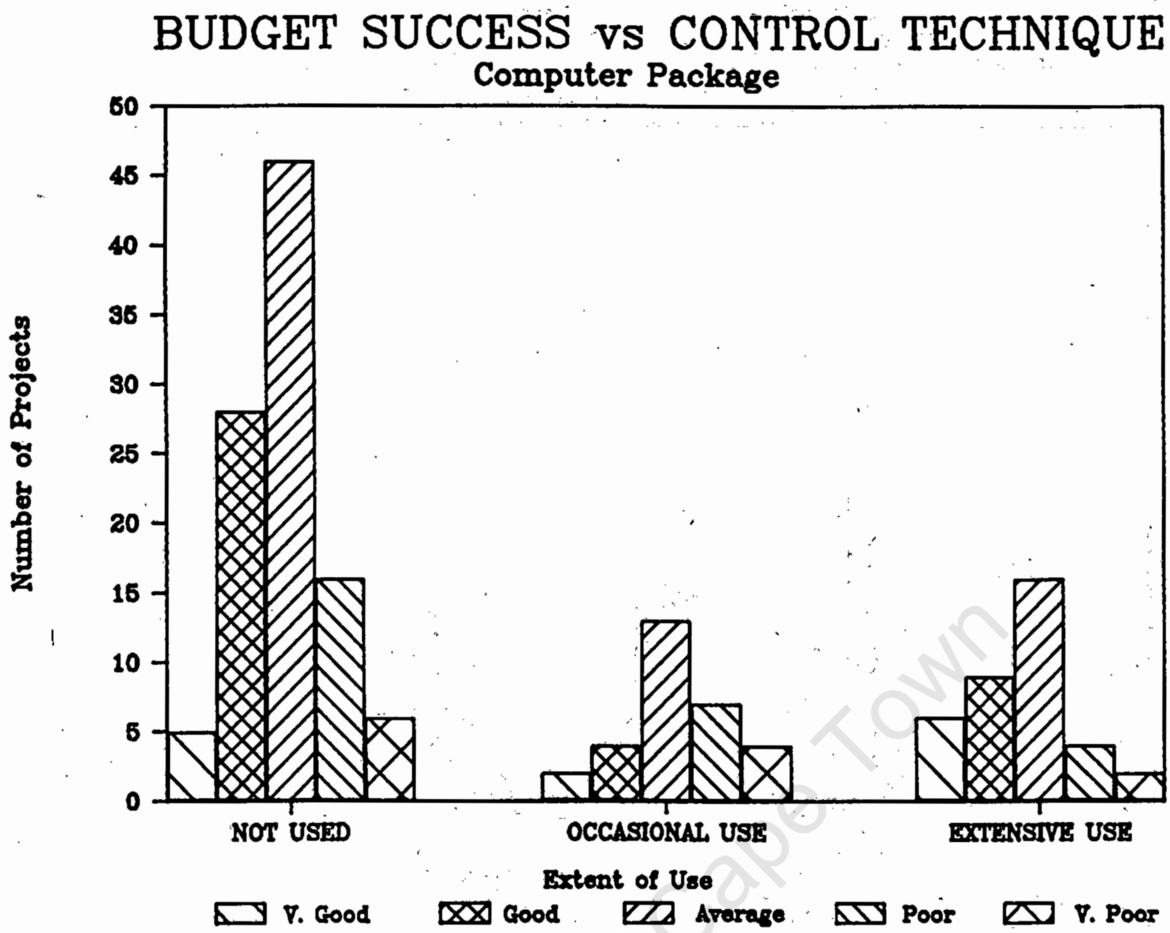
Line of Balance

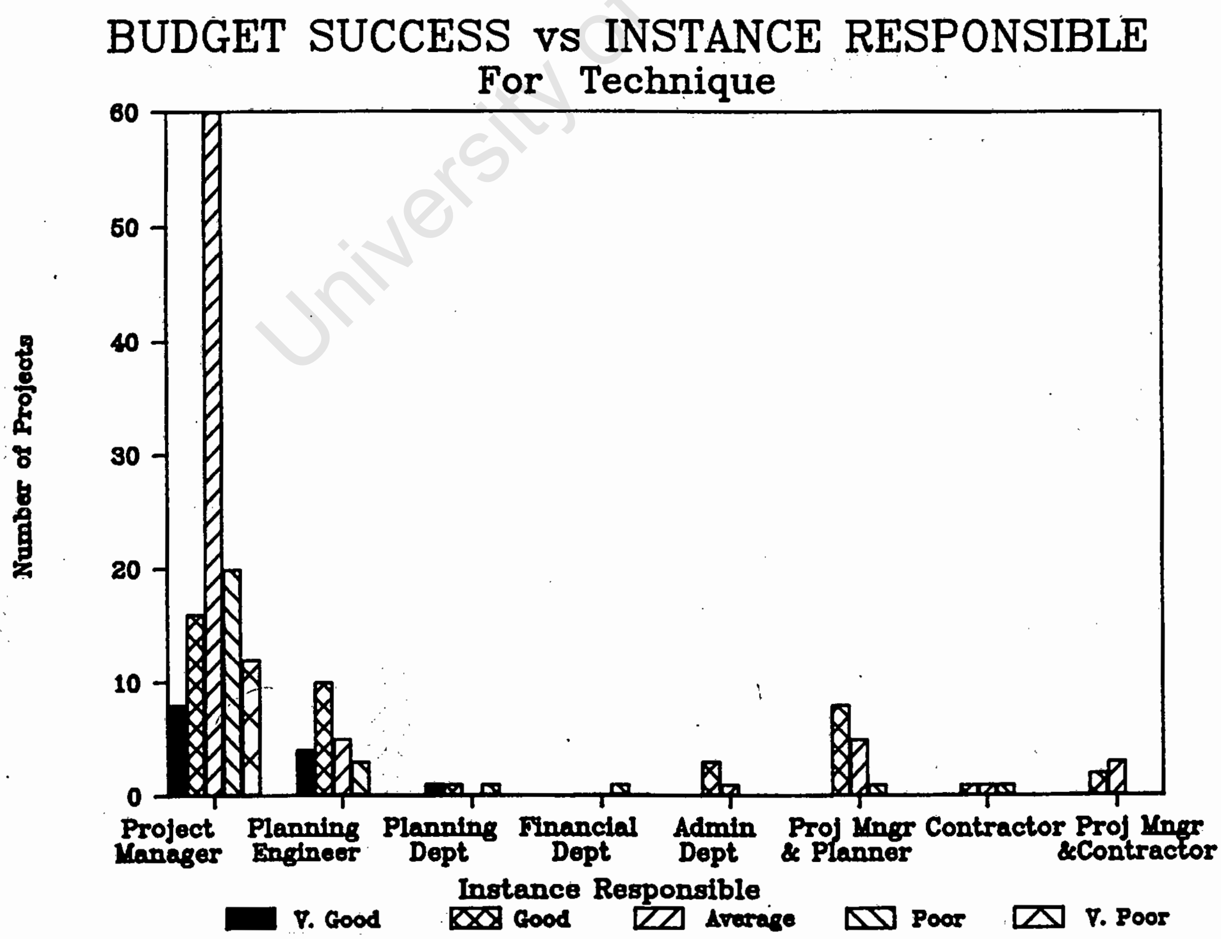


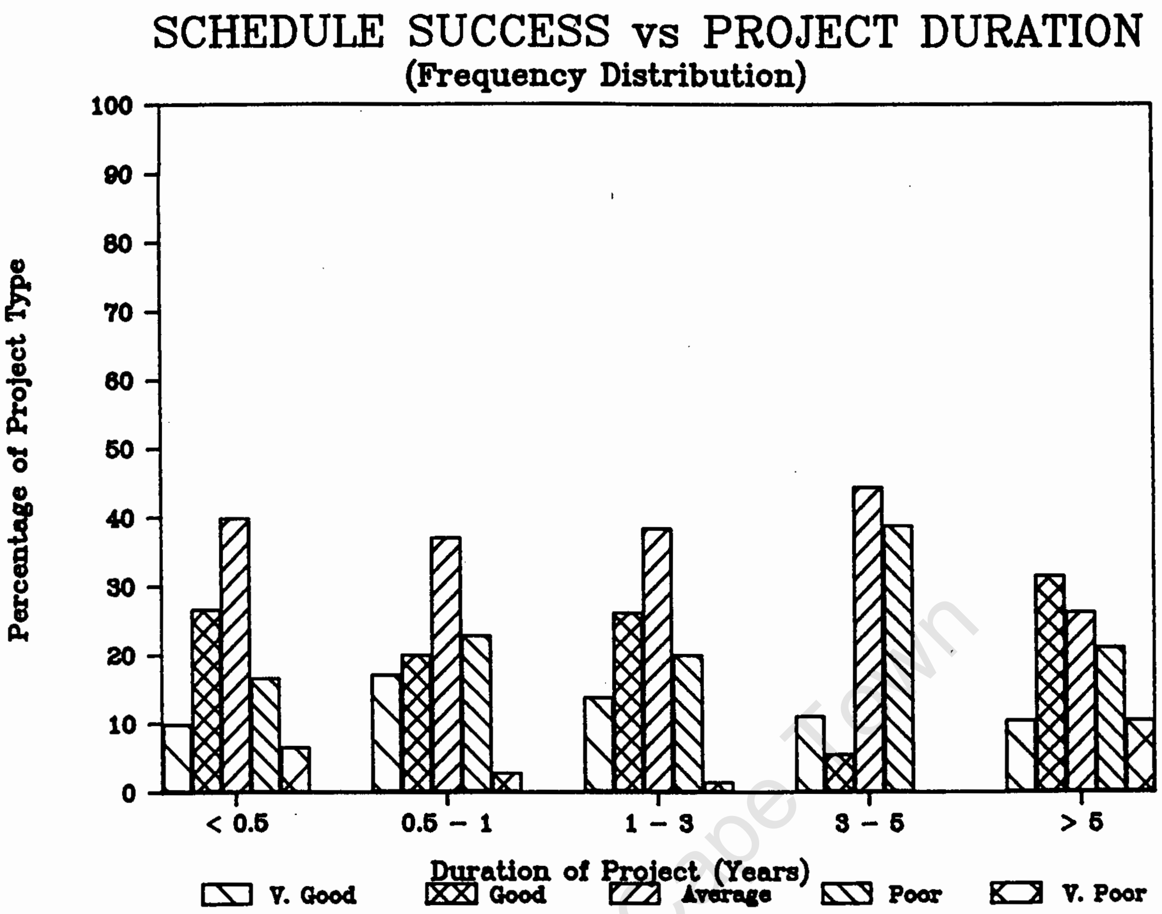
BUDGET SUCCESS vs CONTROL TECHNIQUE

"S" Curves

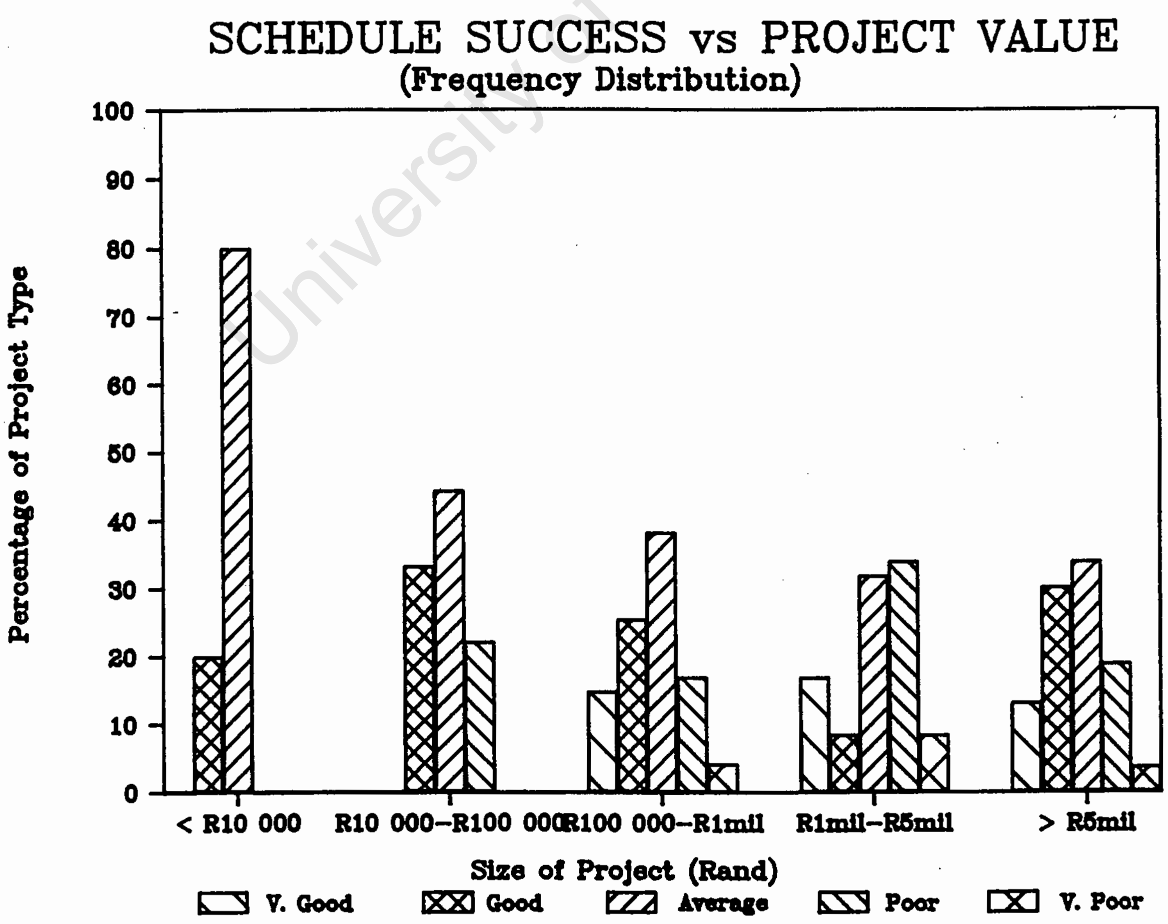



BUDGET SUCCESS vs CONTROL TECHNIQUE
Computer Package
Number of Projects
0
5
10
15
20
25
30
35
40
45
50
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

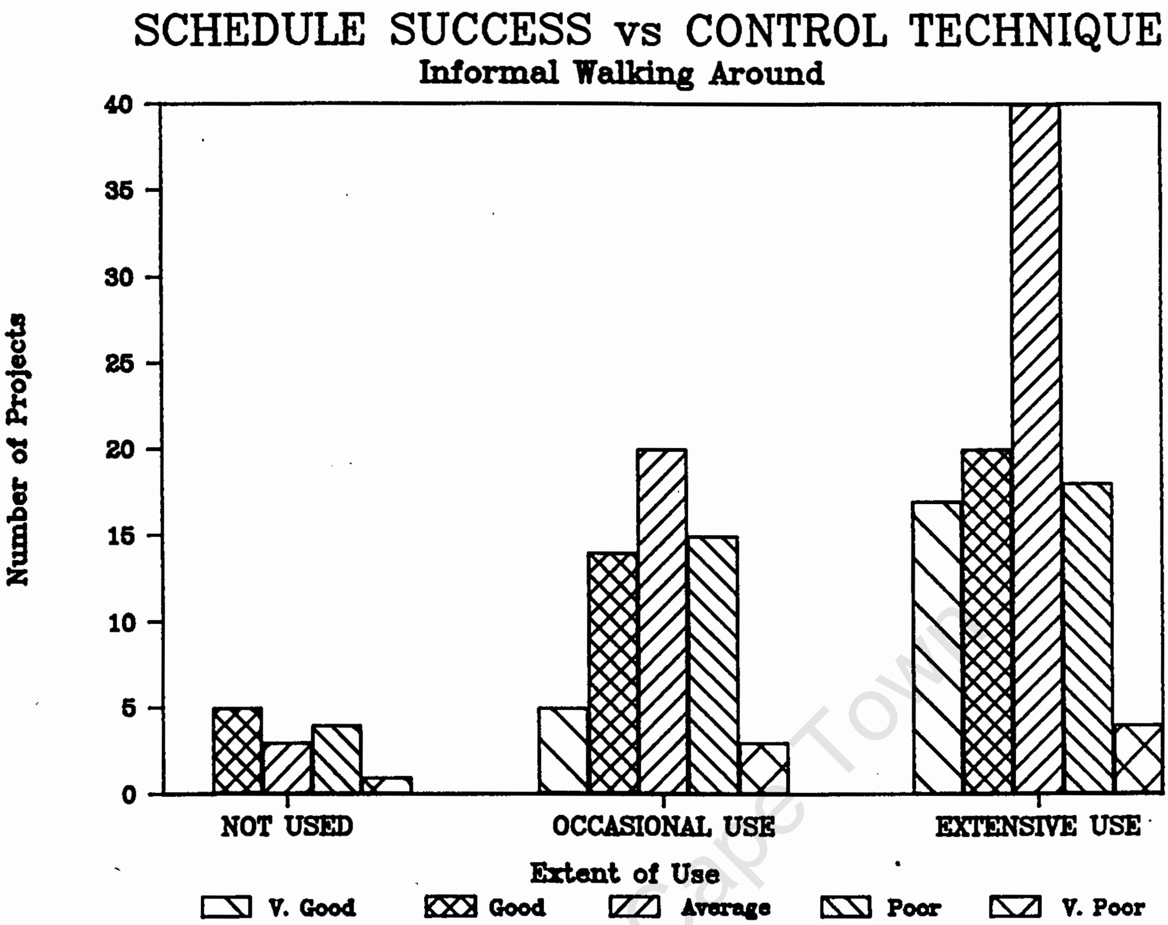

BUDGET SUCCESS vs INSTANCE RESPONSIBLE
For Technique
Number of Projects
0
10
20
30
40
50
60
Project Manager
Planning Engineer
Planning Dept
Financial Dept
Admin Dept
Proj Mngr & Planner
Contractor
Proj Mngr &Contractor
Instance Responsible
V. Good
Good
Average
Poor
V. Poor

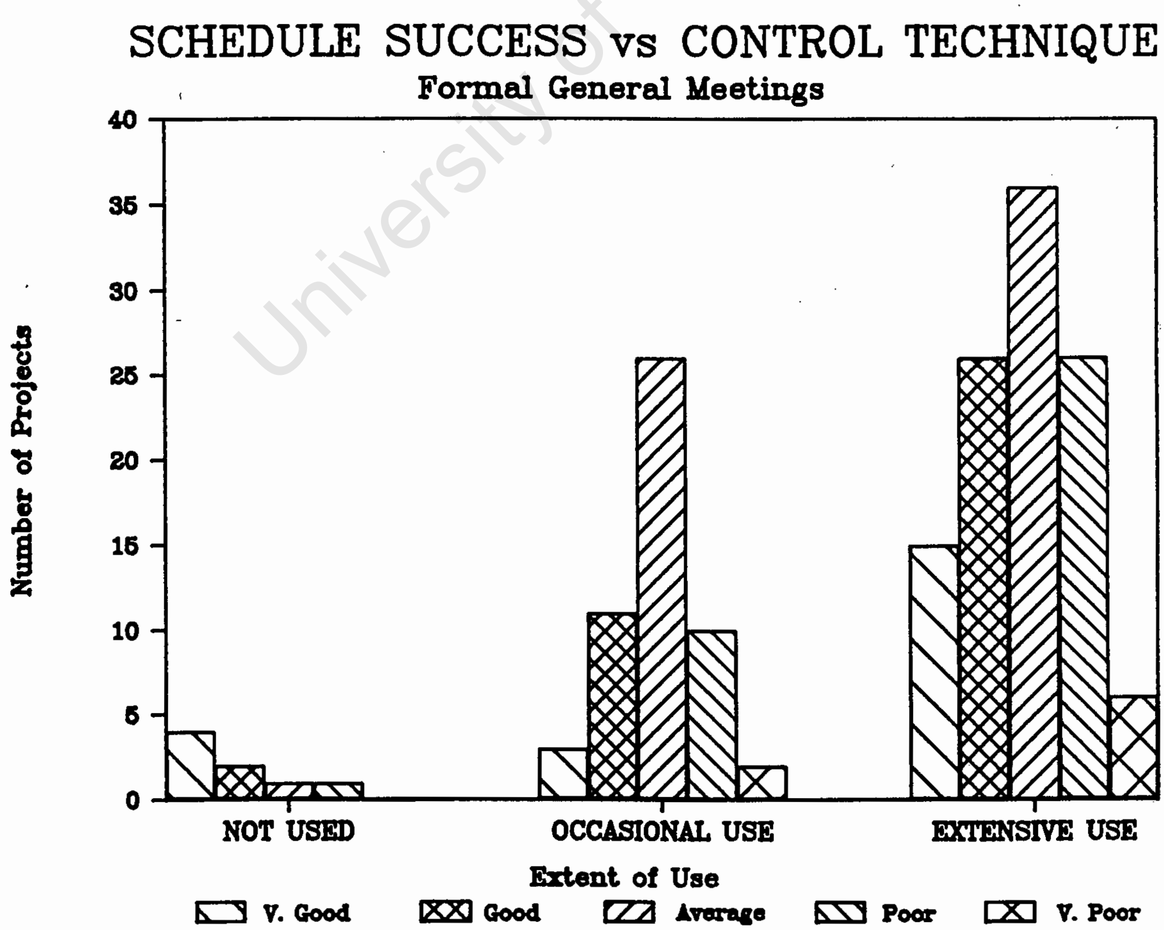


SCHEDULE SUCCESS vs PROJECT DURATION
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
< 0.5
0.5 – 1
1 – 3
3 – 5
> 5
Duration of Project (Years)
V. Good
Good
Average
Poor
V. Poor

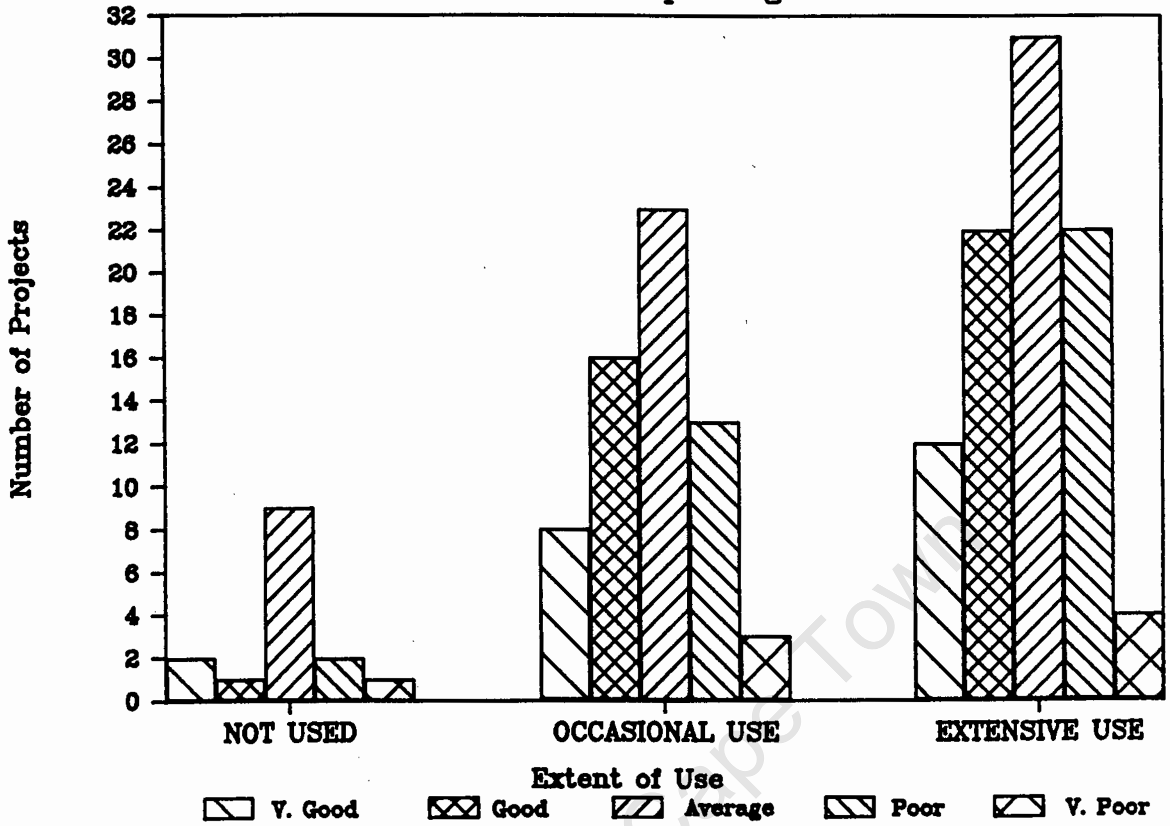


SCHEDULE SUCCESS vs PROJECT VALUE
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
< R10 000
R10 000–R100 000
R100 000–R1mil
R1mil–R5mil
> R5mil
Size of Project (Rand)
V. Good
Good
Average
Poor
V. Poor

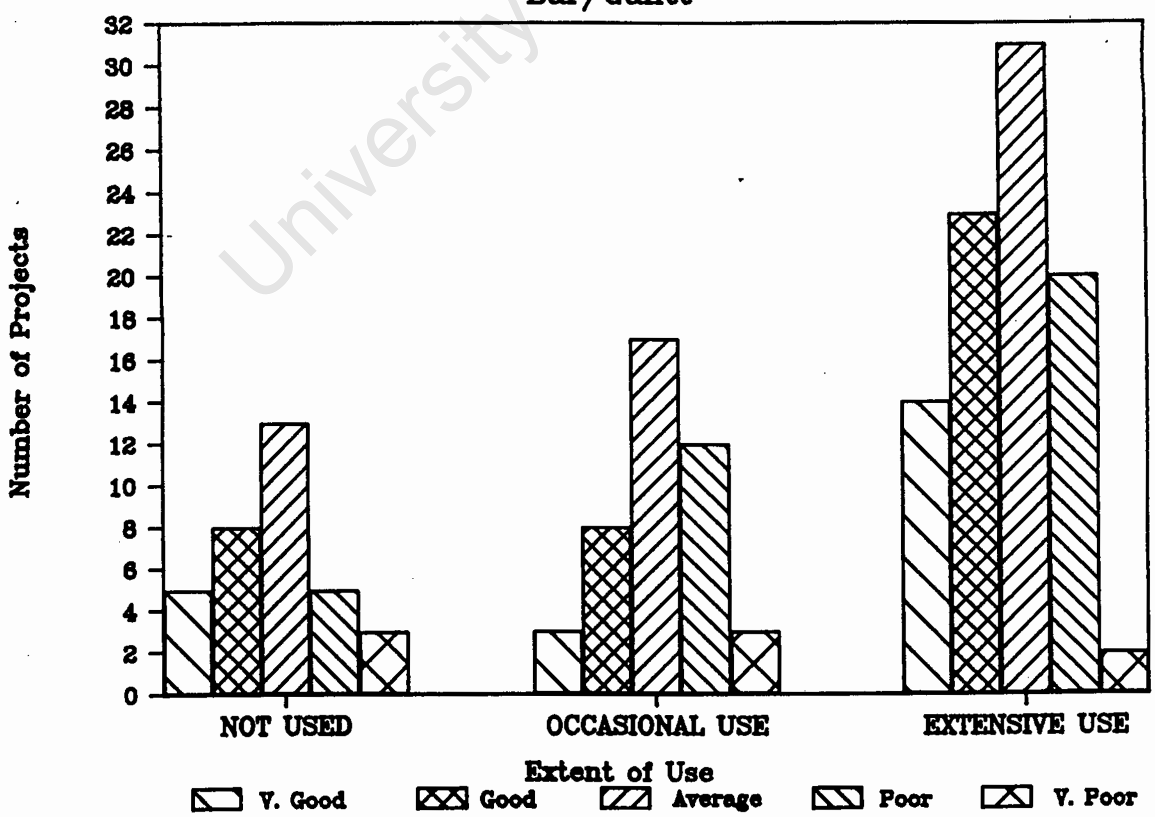

SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Informal Walking Around
Number of Projects
40
35
30
25
20
15
10
5
0
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

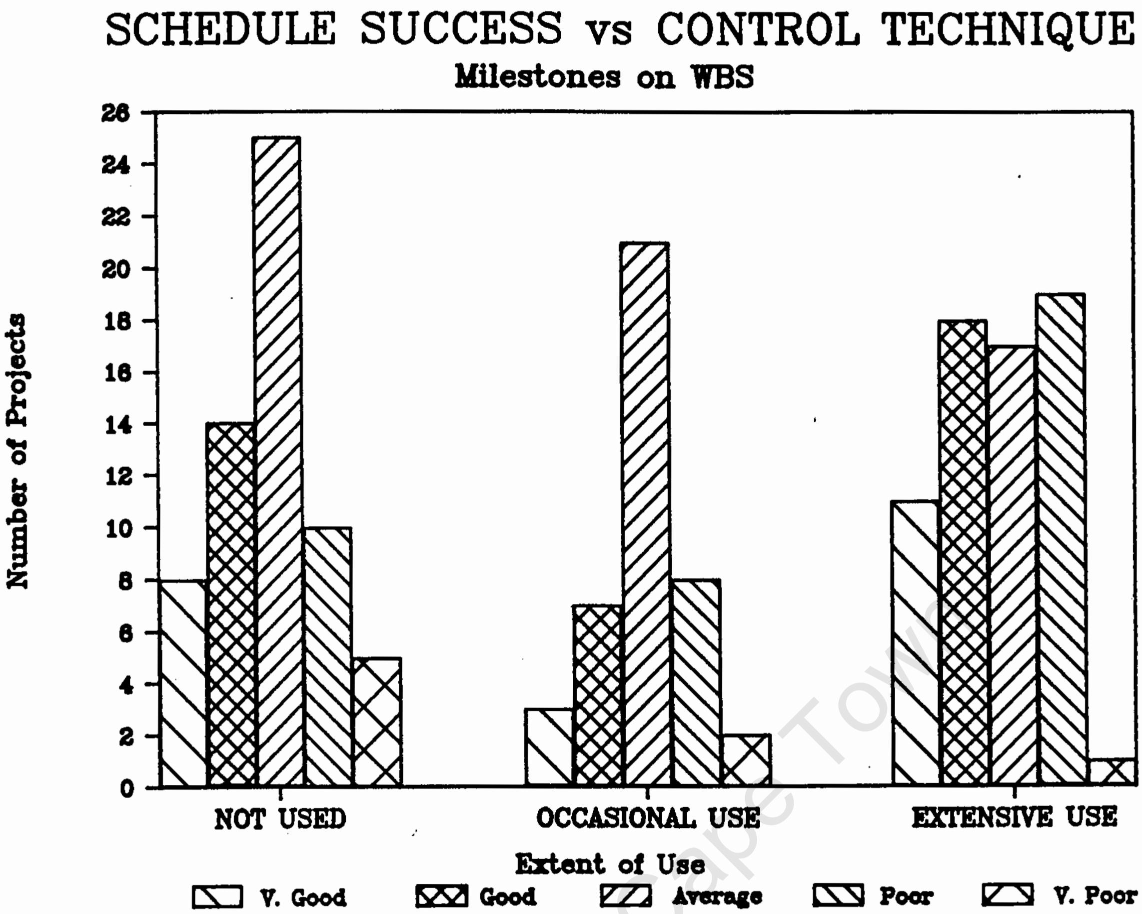

SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Formal General Meetings
Number of Projects
40
35
30
25
20
15
10
5
0
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

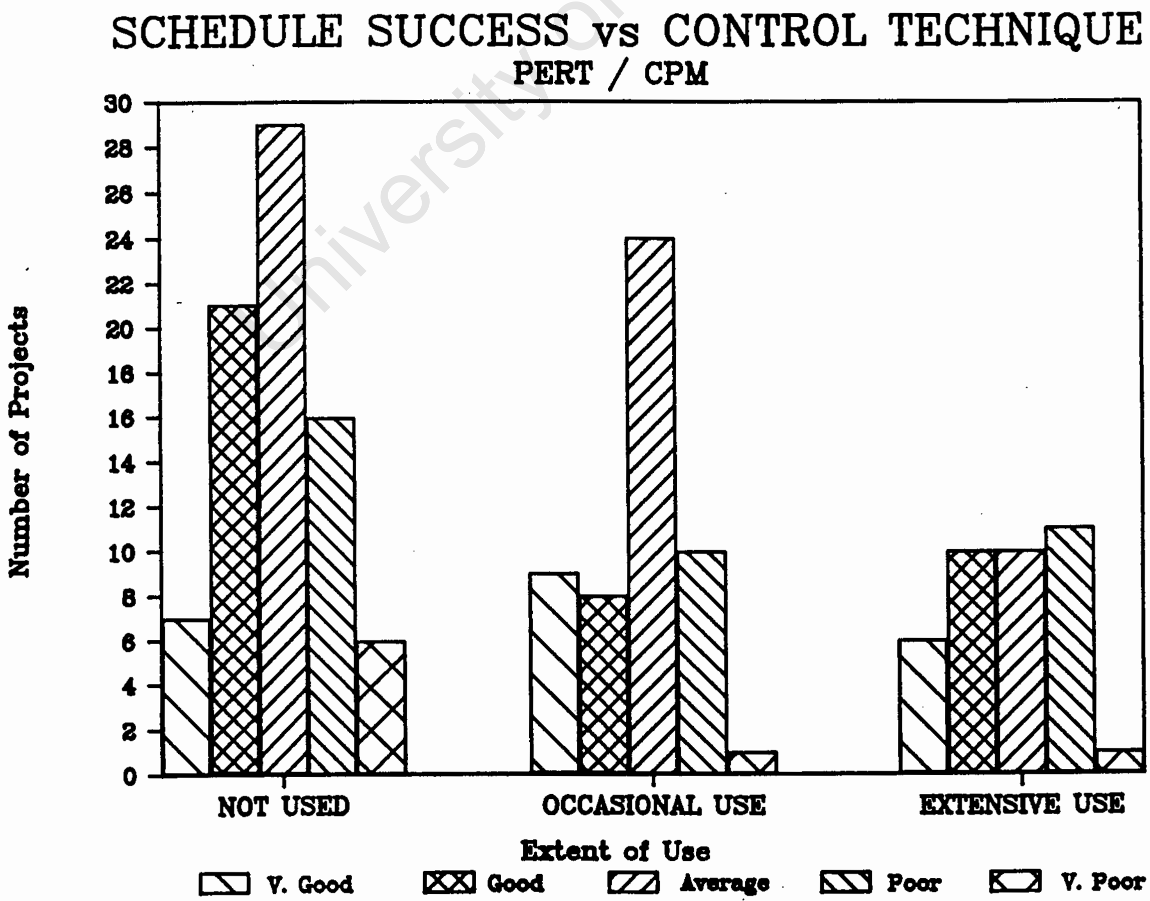
SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Formal Reporting



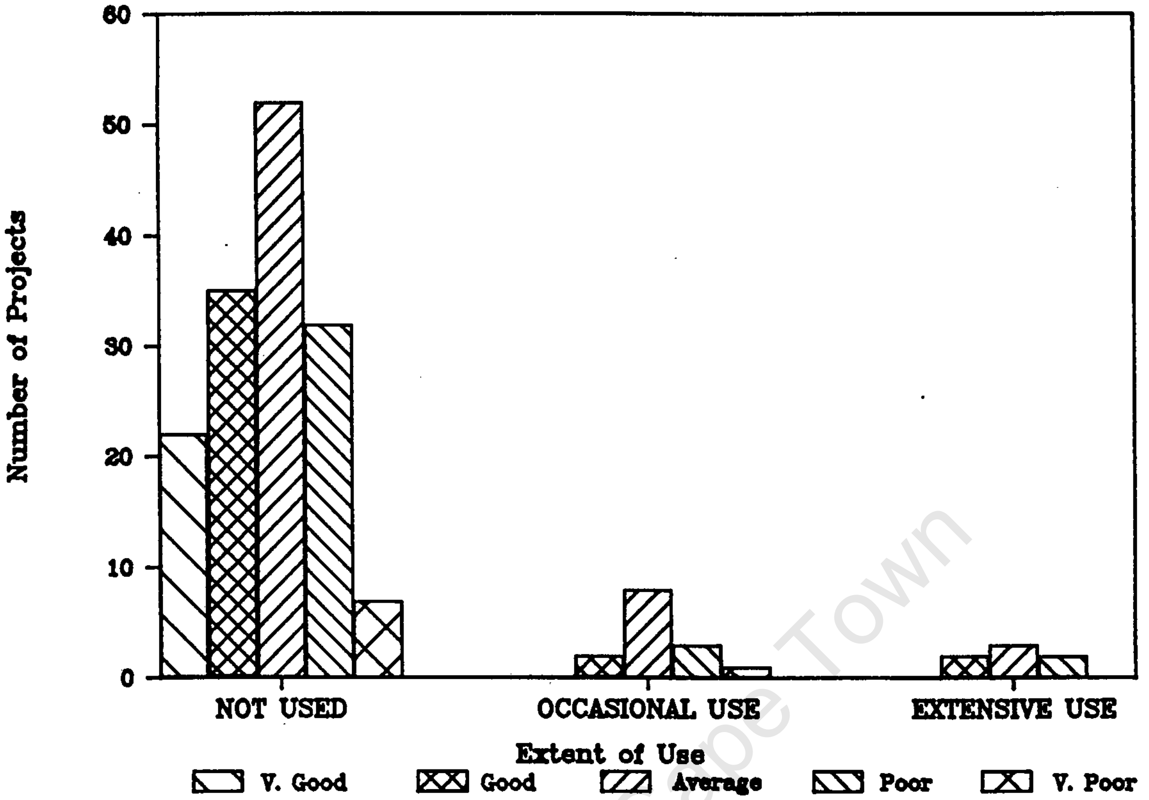
SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Bar/Gantt



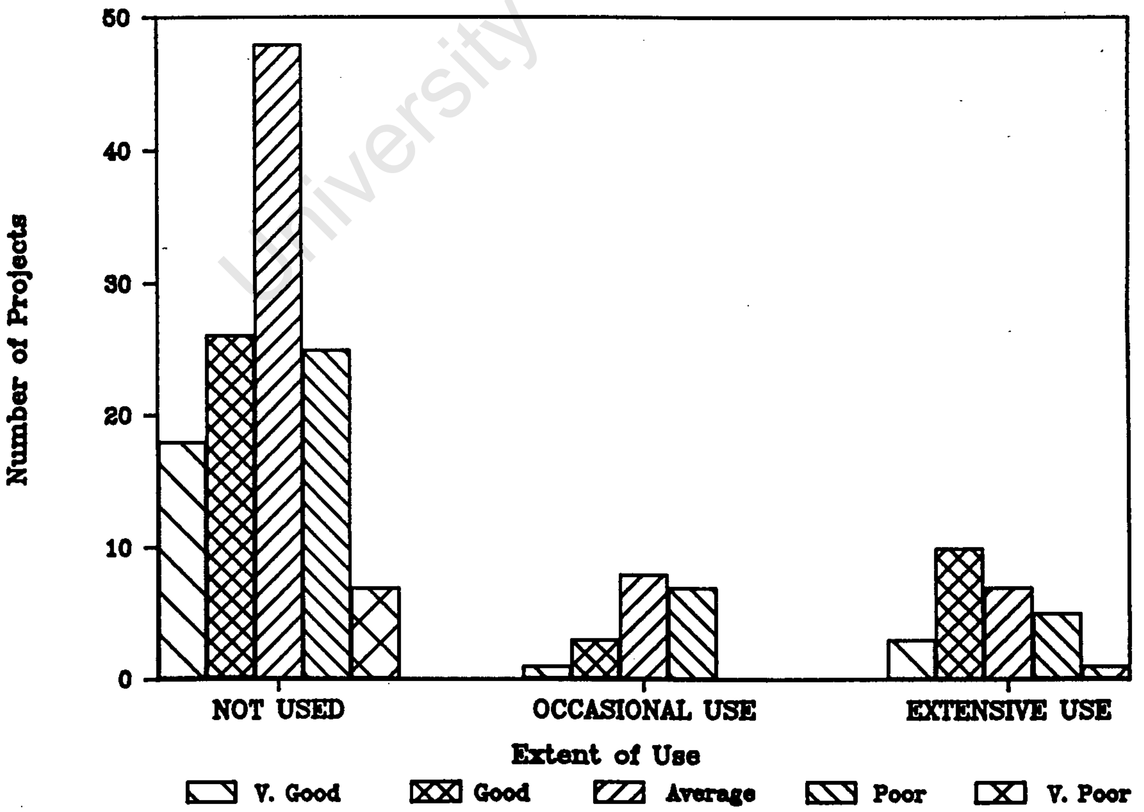

SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Milestones on WBS
Number of Projects
0
2
4
6
8
10
12
14
16
18
20
22
24
26
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor


SCHEDULE SUCCESS vs CONTROL TECHNIQUE
PERT / CPM
Number of Projects
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

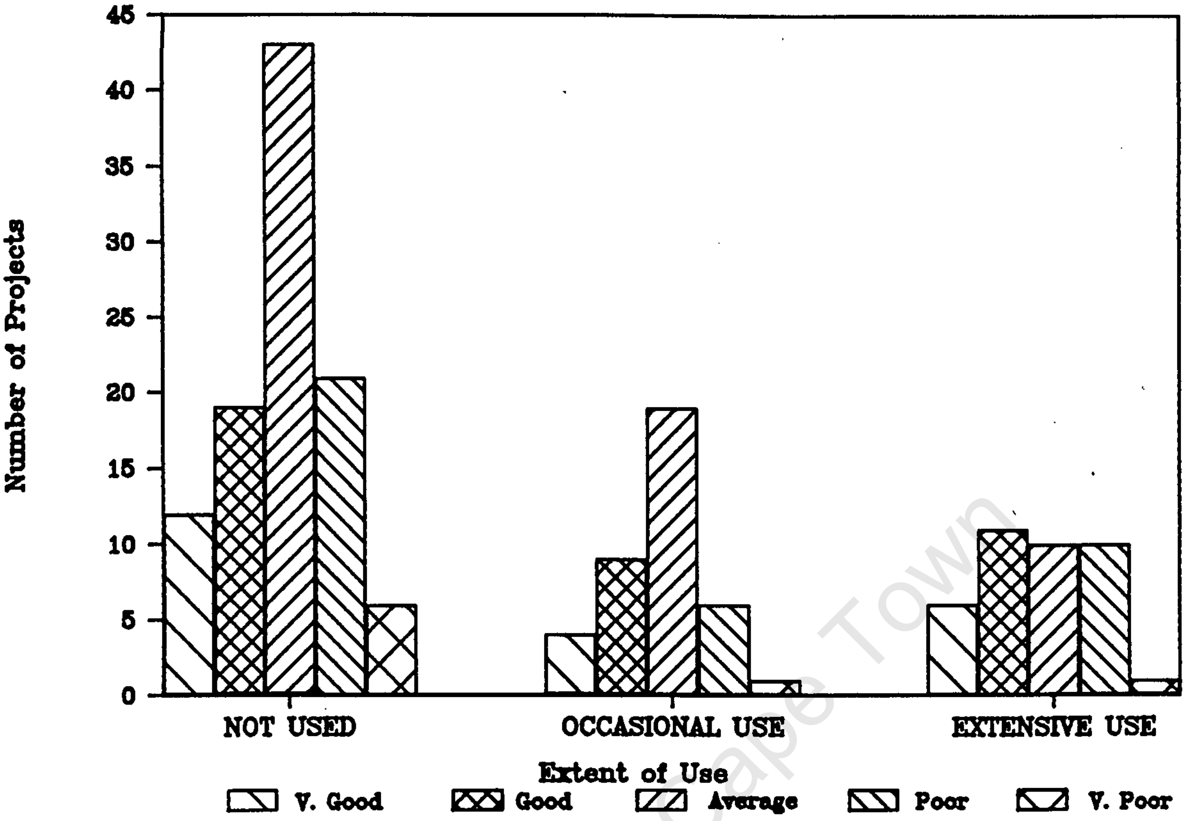
SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Line of Balance



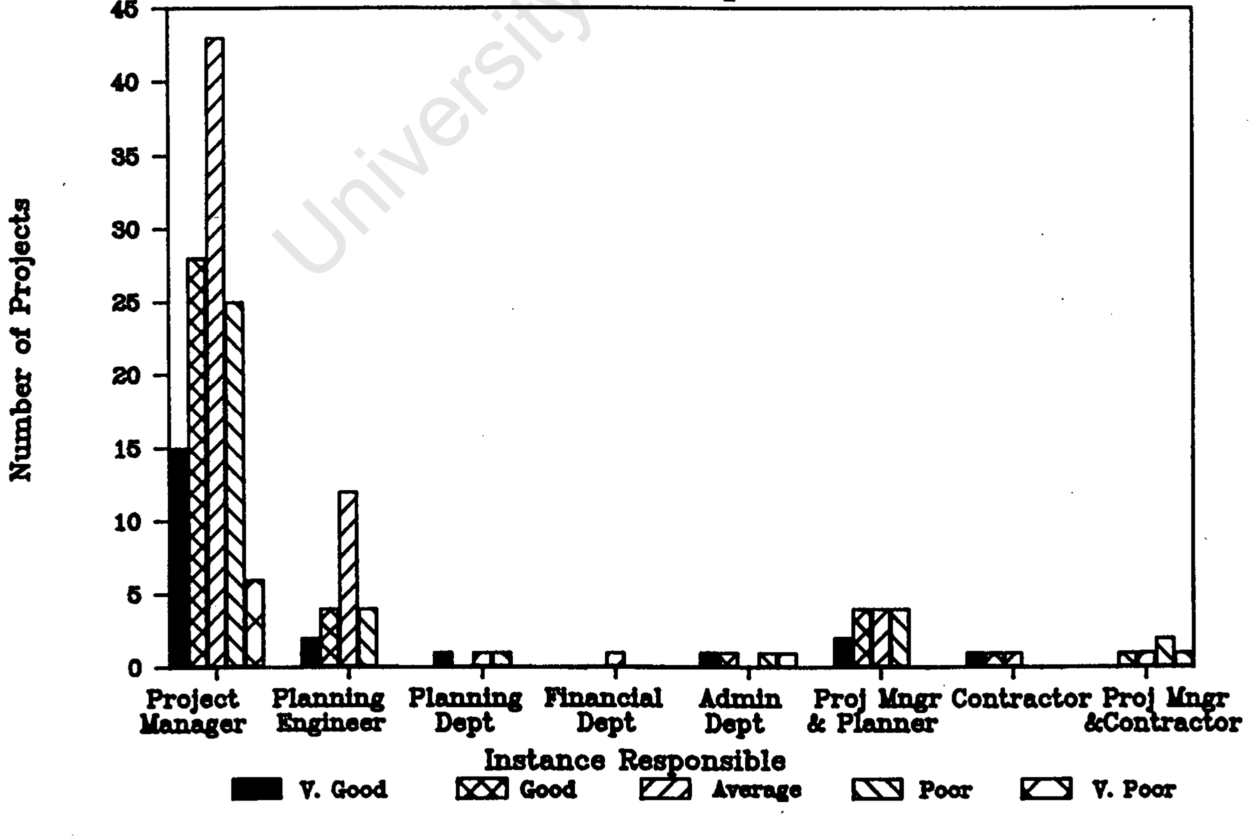
SCHEDULE SUCCESS vs CONTROL TECHNIQUE
"S" Curves

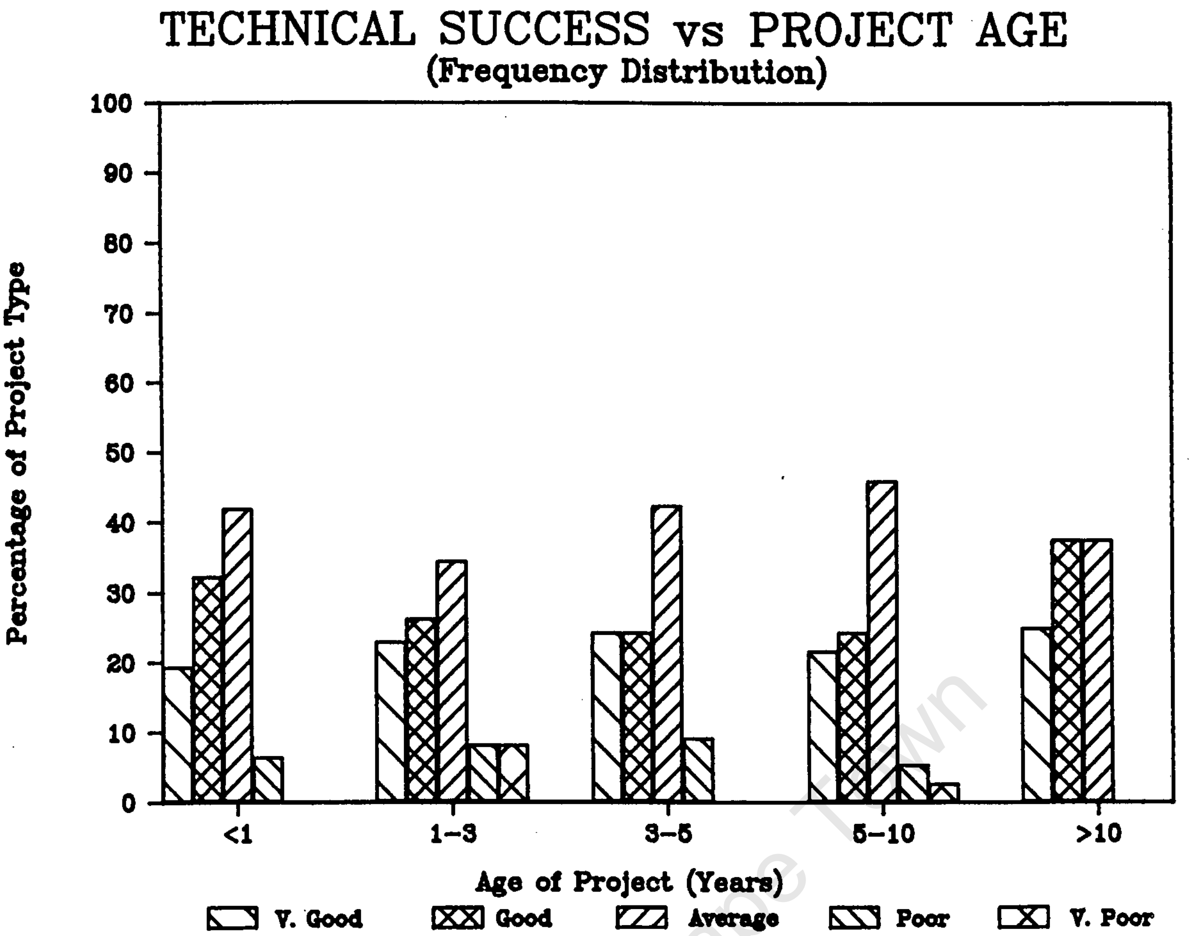


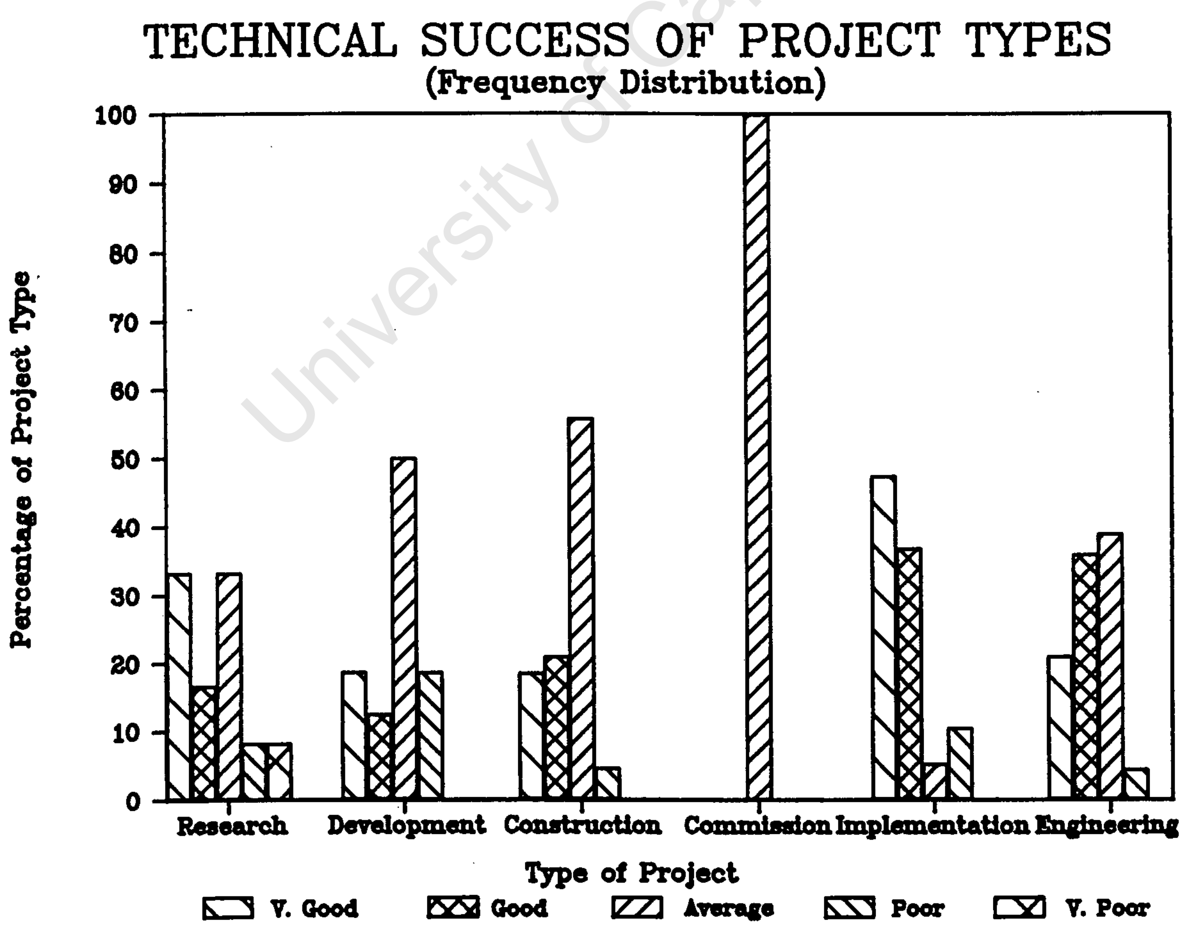
SCHEDULE SUCCESS vs CONTROL TECHNIQUE
Computer Package

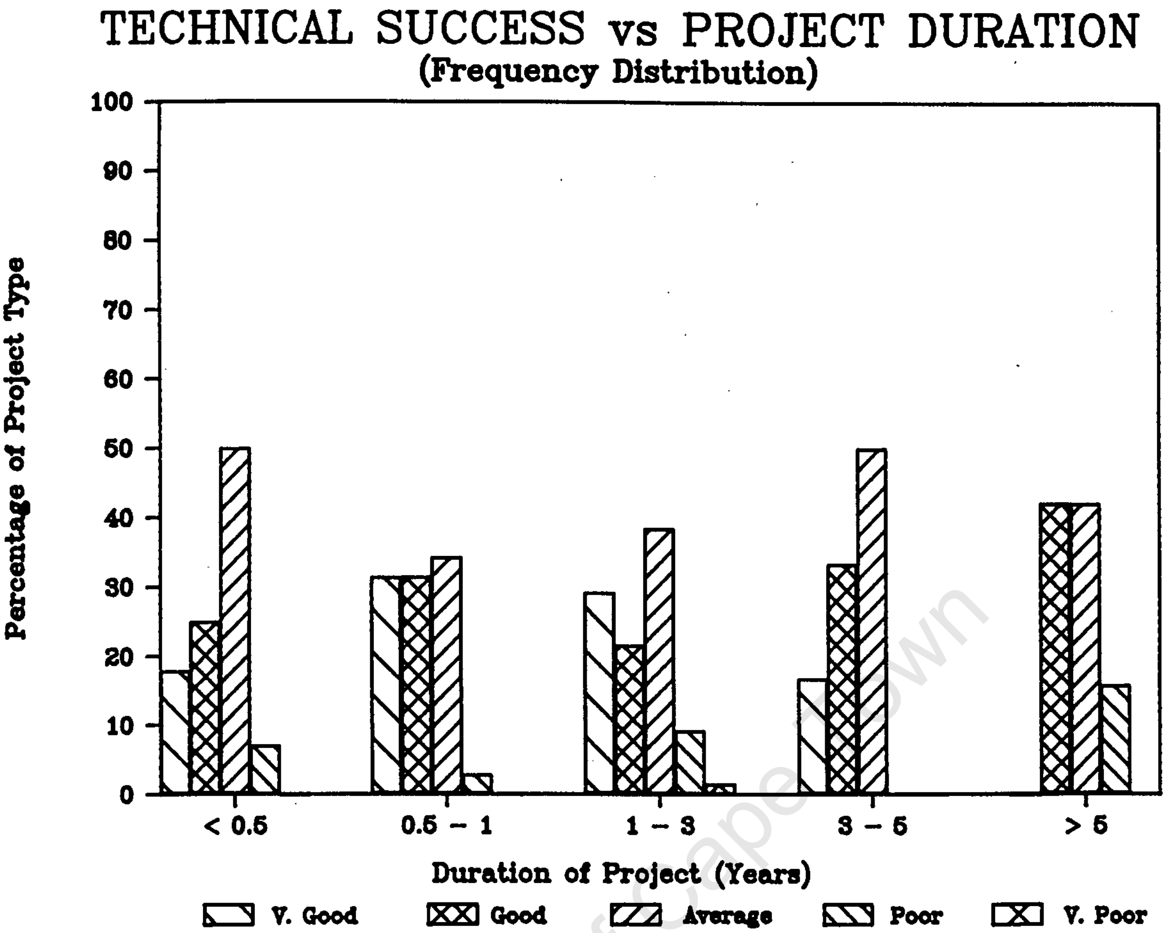


SCHEDULE SUCCESS vs INSTANCE RESPONSIBLE
For Technique

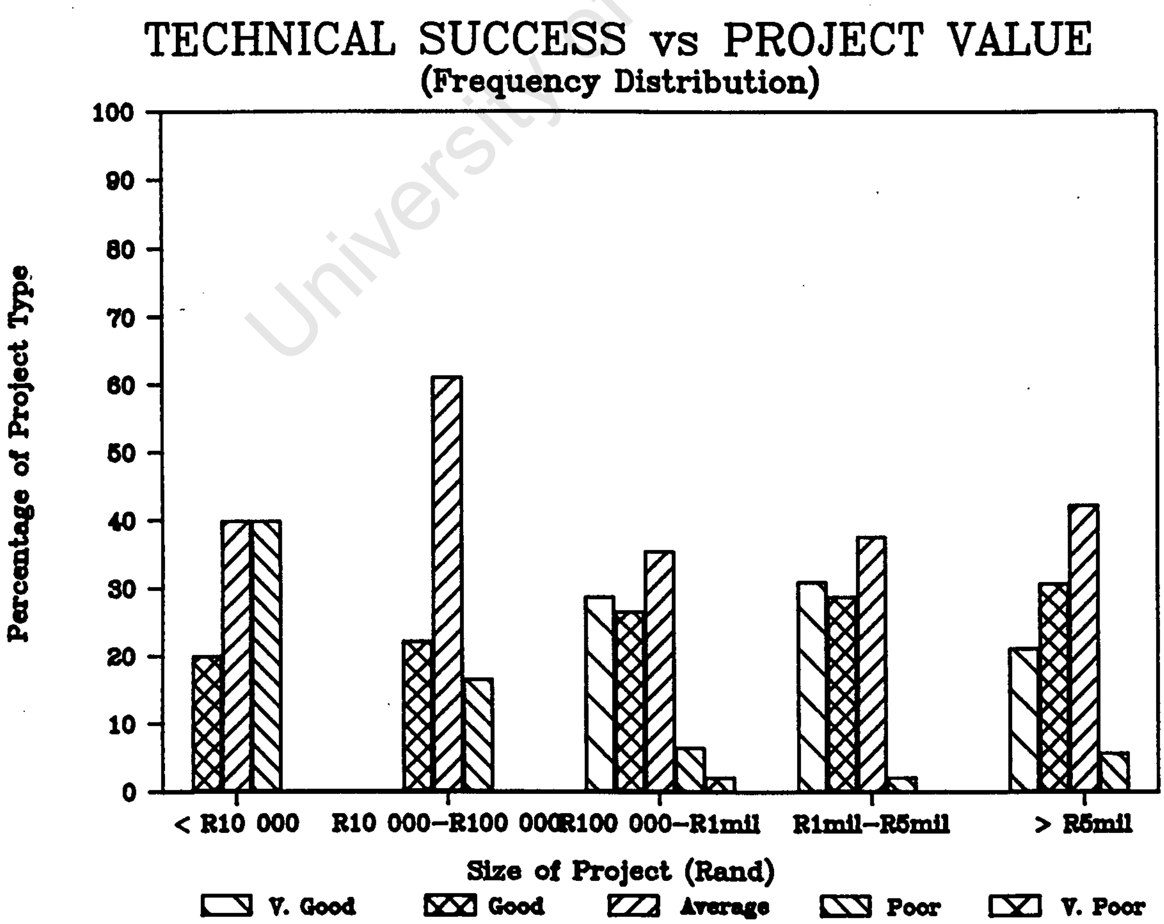



TECHNICAL SUCCESS vs PROJECT AGE
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
<1
1-3
3-5
5-10
>10
Age of Project (Years)
V. Good
Good
Average
Poor
V. Poor

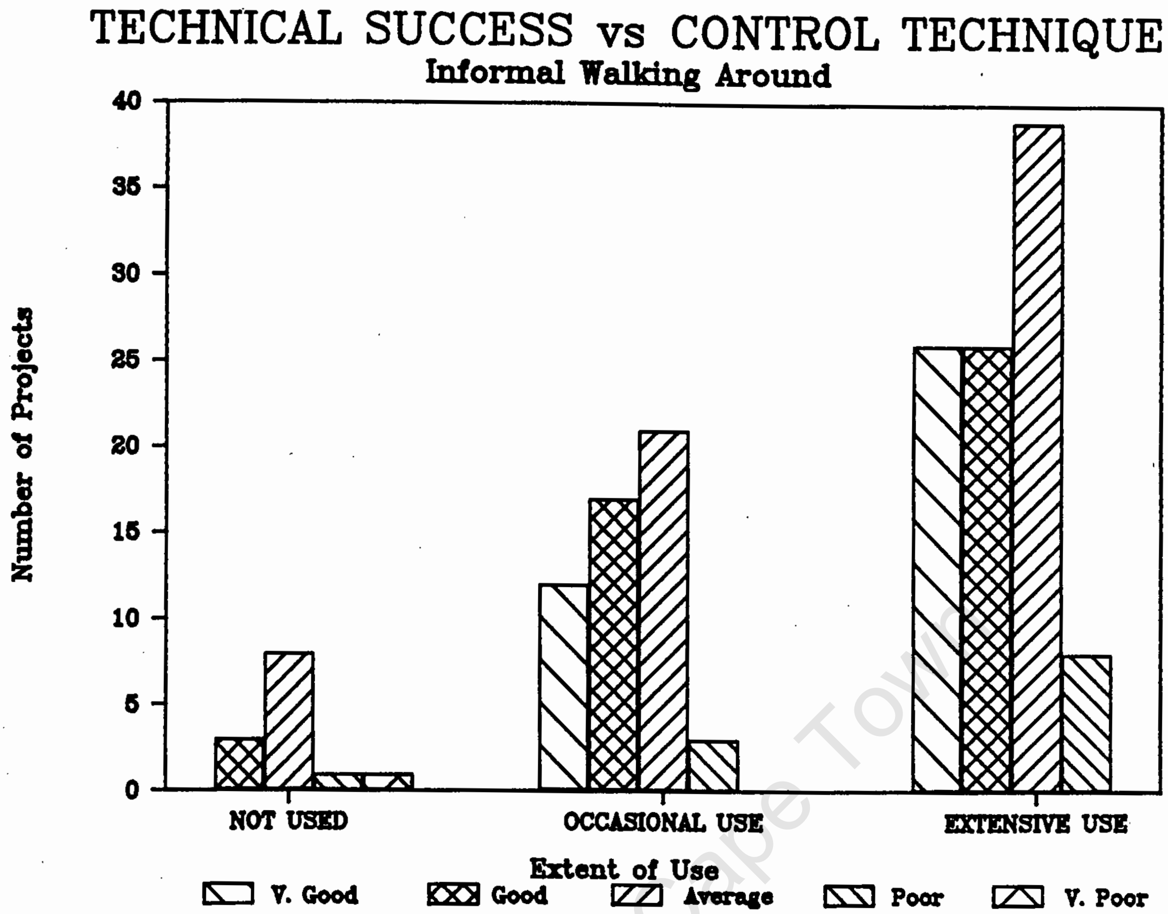

TECHNICAL SUCCESS OF PROJECT TYPES
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
Research
Development
Construction
Commission
Implementation
Engineering
Type of Project
V. Good
Good
Average
Poor
V. Poor

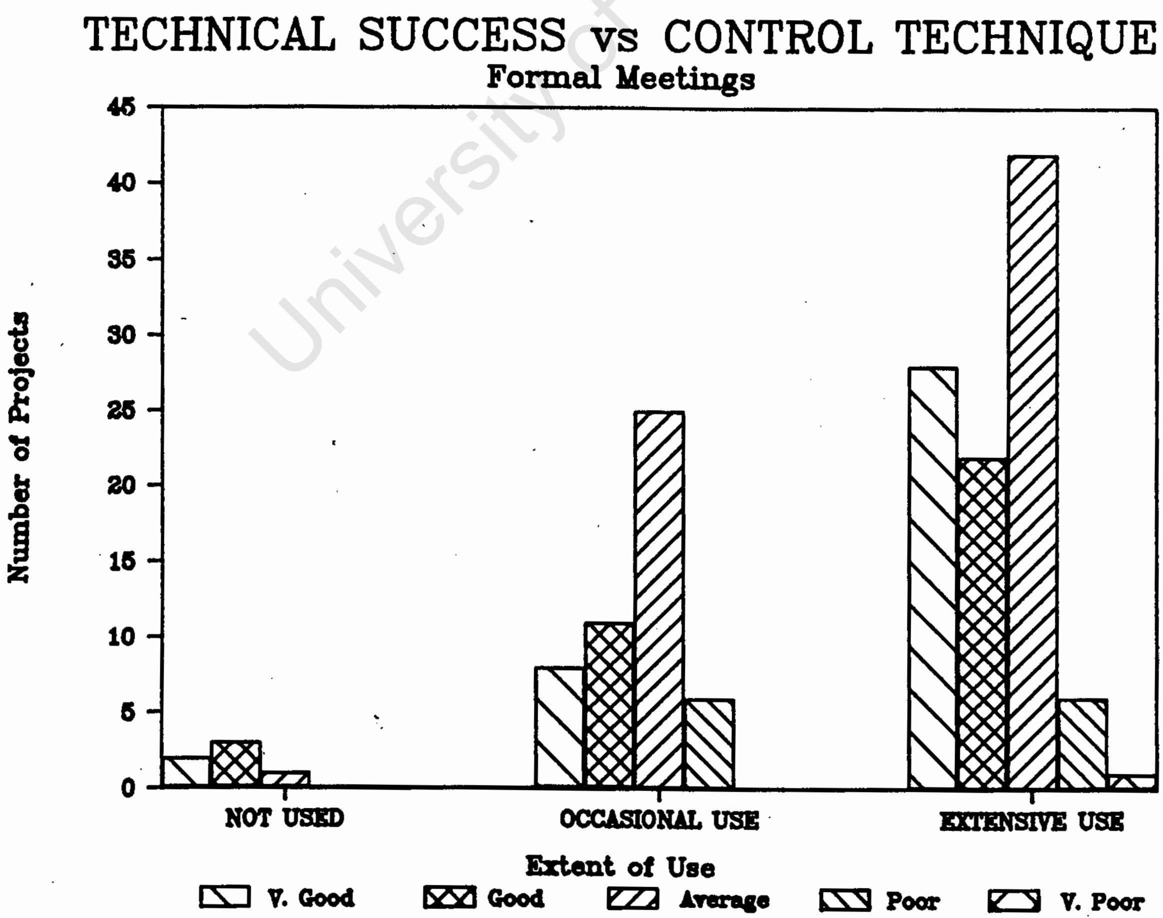


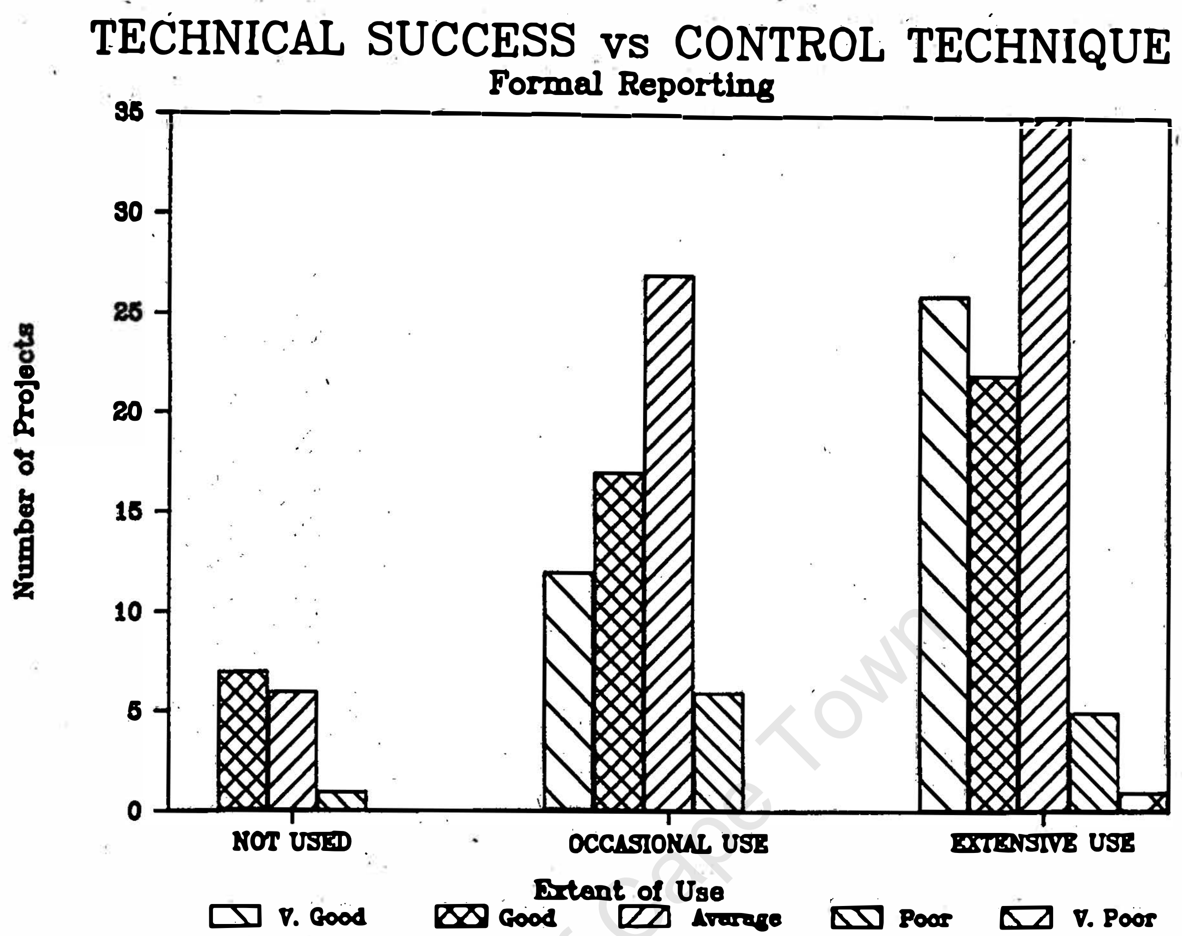
TECHNICAL SUCCESS vs PROJECT DURATION
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
< 0.5
0.5 – 1
1 – 3
3 – 5
> 5
Duration of Project (Years)
V. Good
Good
Average
Poor
V. Poor

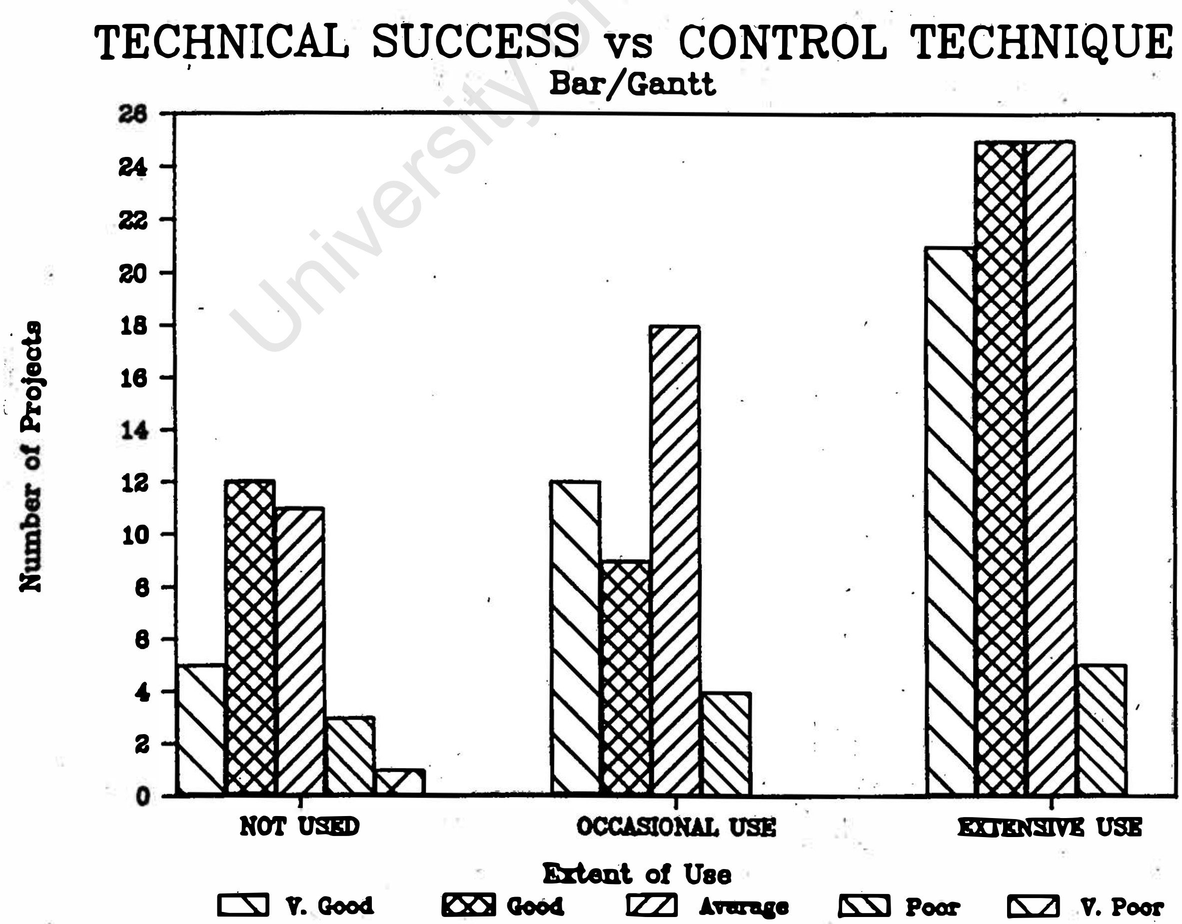


TECHNICAL SUCCESS vs PROJECT VALUE
(Frequency Distribution)
Percentage of Project Type
0
10
20
30
40
50
60
70
80
90
100
< R10 000
R10 000–R100 000
R100 000–R1mil
R1mil–R5mil
> R5mil
Size of Project (Rand)
V. Good
Good
Average
Poor
V. Poor

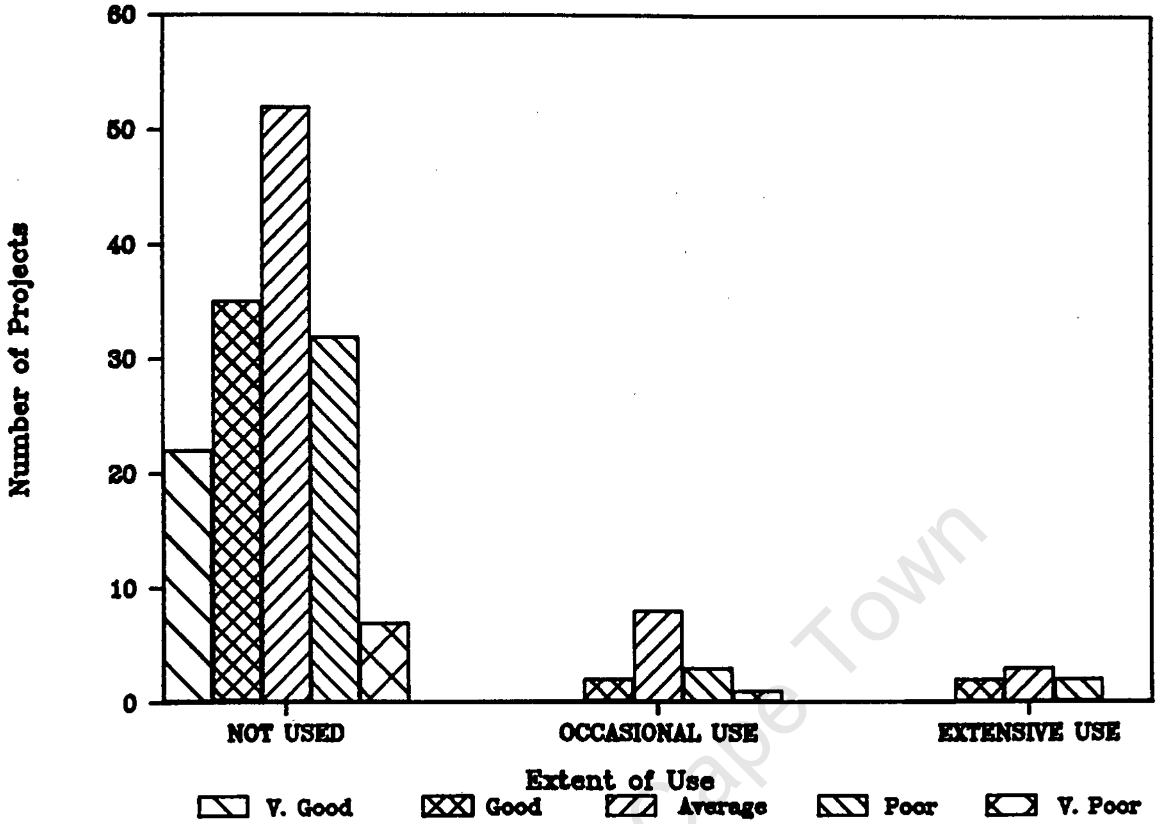

TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Informal Walking Around
Number of Projects
0
5
10
15
20
25
30
35
40
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor


TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Formal Meetings
Number of Projects
0
5
10
15
20
25
30
35
40
45
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

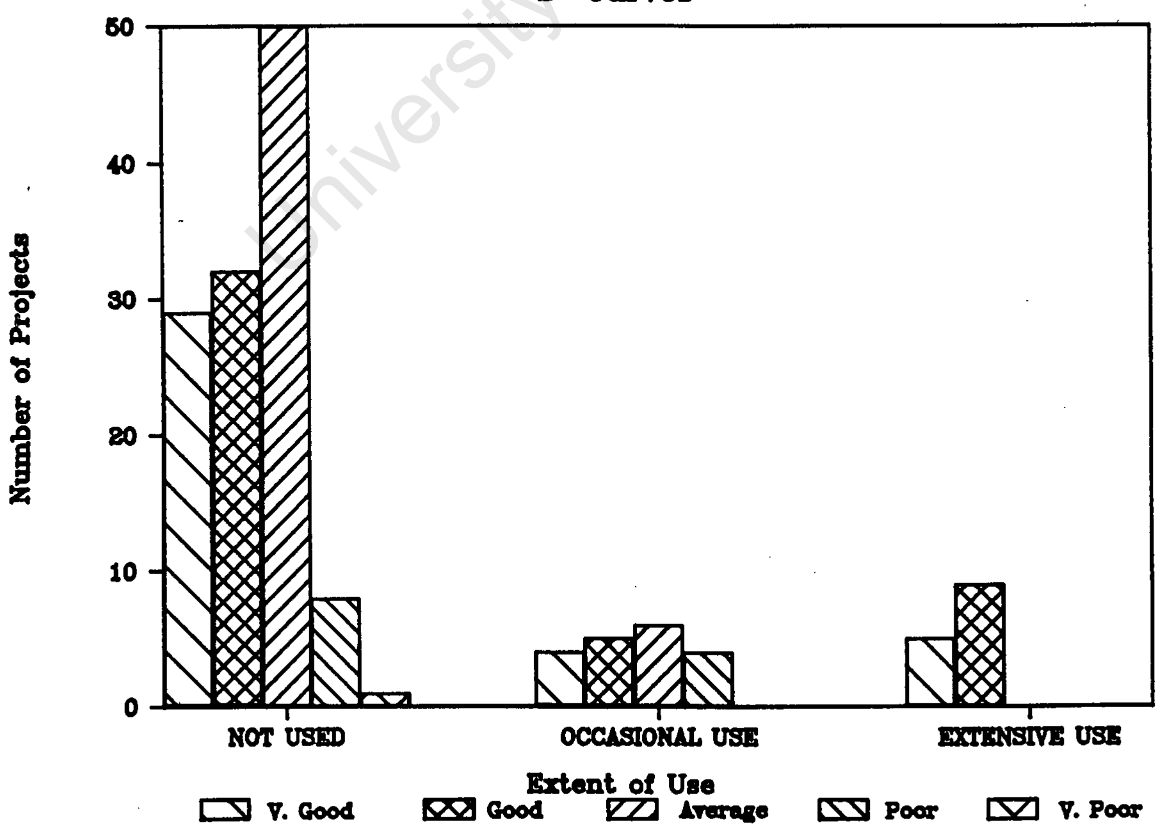

TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Formal Reporting
Number of Projects
35
30
25
20
15
10
5
0
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

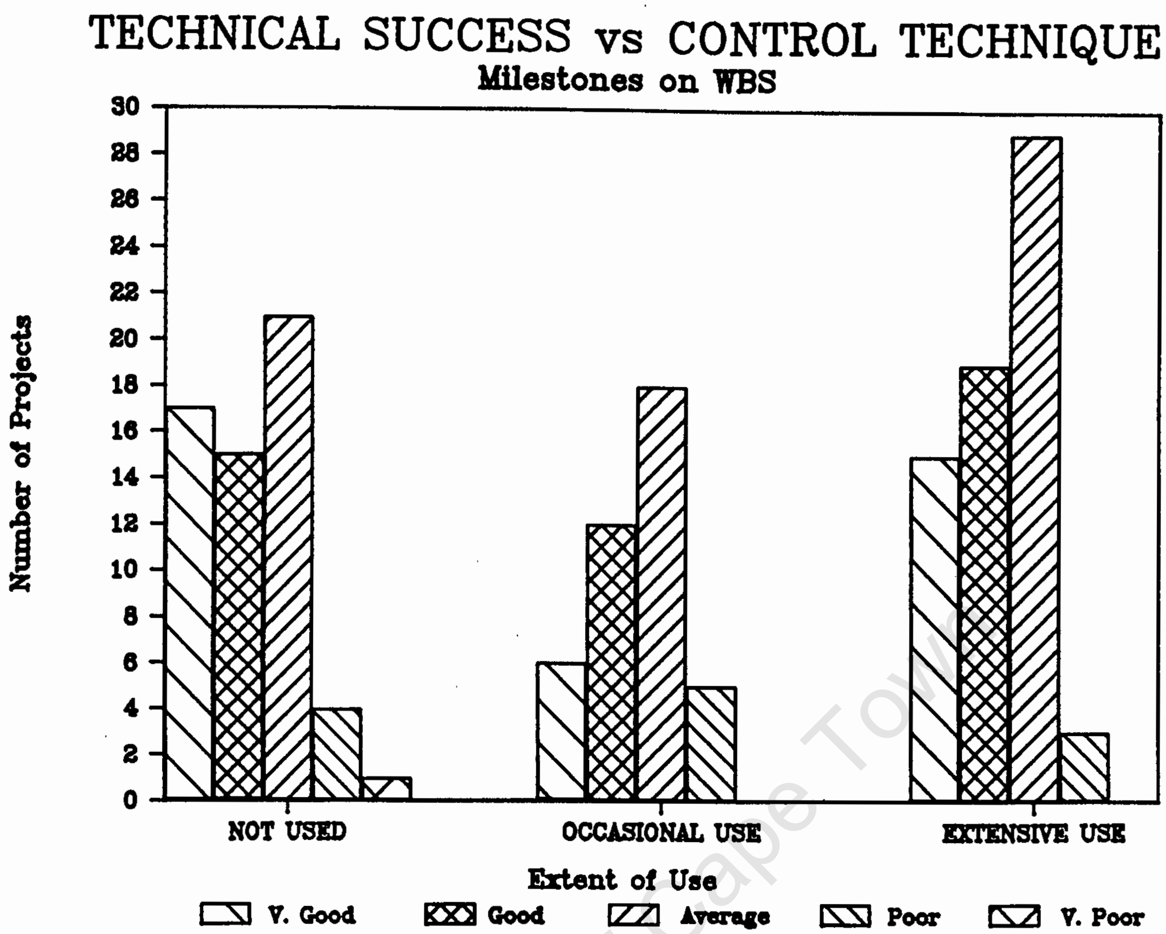

TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Bar/Gantt
Number of Projects
26
24
22
20
18
16
14
12
10
8
6
4
2
0
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

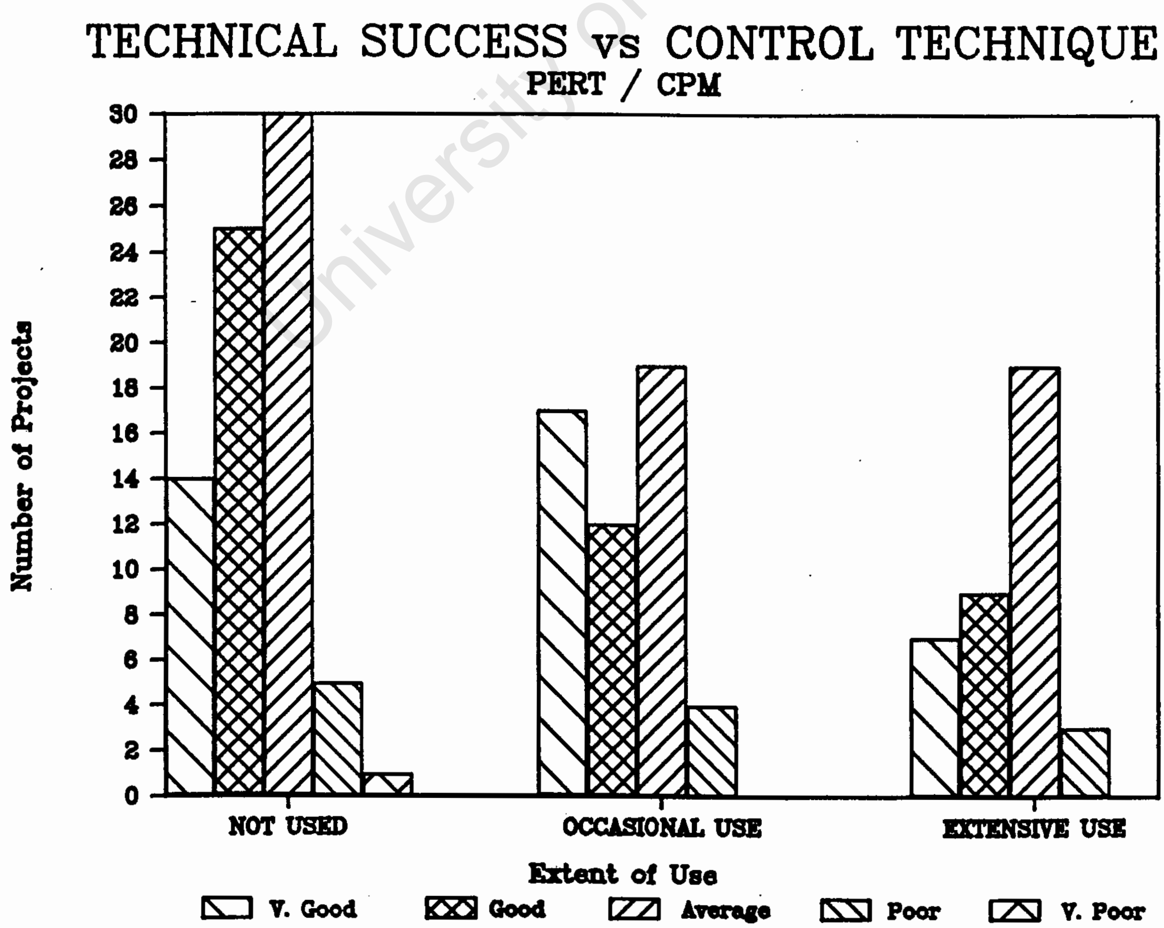
TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Line of Balance



TECHNICAL SUCCESS vs CONTROL TECHNIQUE
"S" Curves




TECHNICAL SUCCESS vs CONTROL TECHNIQUE
Milestones on WBS
Number of Projects
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor


TECHNICAL SUCCESS vs CONTROL TECHNIQUE
PERT / CPM
Number of Projects
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
NOT USED
OCCASIONAL USE
EXTENSIVE USE
Extent of Use
V. Good
Good
Average
Poor
V. Poor

APPENDIX C

ANALYSIS OF VARIANCE

ANALYSIS OF VARIANCE

ONE-WAY ANOVA TABLES

The following tables indicate those values which were regarded as significant in the one-way Analysis of Variance test (ANOVA). The significance level is taken as 5% with the F-ratio, in order to disprove the null hypothesis.

TABLE 1 : Success = f(Characteristic)

	Cost	Schedule	Technical
Age	0.059	0.008	-
Type	-	0.002	0.021
Value	-	-	0.005
Duration	0.000	-	-

TABLE 2 : Success = f(Control Technique)

	Cost	Schedule	Technical
Informal meetings	-	-	0.032
Formal meetings	-	0.029	0.059
Reporting	-	-	-
Bar / Gantt	-	-	-
Milestone	-	-	-
PERT	-	-	-
LOB	-	-	0.032
"S" curves	0.042	-	-
P.C. Packages	0.045	-	-

TABLE 3 : Success = f(Responsible Person)

	Cost	Schedule	Technical
Person	0.007	-	-

TABLE 4 : Control Technique = f(Characteristic)

	Age	Type	Value	Duration
Informal meetings	-	-	-	-
Formal meetings	0.024	0.012	0.000	-
Reporting	-	-	0.000	0.018
Bar / Gantt	-	0.002	0.006	-
Milestone	-	-	0.000	0.000
PERT	-	-	0.007	0.005
LOB	-	-	0.001	-
"S" curves	-	0.007	0.000	0.000
P.C. Packages	-	-	0.000	0.003

TWO-WAY ANOVA TABLES

The following tables indicate those values which were regarded as significant in the two-way Analysis of Variance (ANOVA). The significance level is taken as 5% with the F-ratio, in order to disprove the null hypothesis.

Figure 5: Success = (Project Age x Control Technique)

	Cost	Schedule	Technical
Informal meetings	-	0.027	-
Formal meetings	-	0.008	-
Reporting	-	0.032	-
Bar / Gantt	-	0.013	-
Milestone	-	0.015	-
PERT	-	0.040	-
LOB	0.013	0.021	0.037
"S" curves	0.018	0.024	-
P.C. Packages	0.040	0.023	-

Figure 6: Success = (Project Type x Control Technique)

	Cost	Schedule	Technical
Informal meetings	-	0.006	0.012
Formal meetings	-	0.002	0.015
Reporting	-	0.007	0.013
Bar / Gantt	-	0.001	0.058
Milestone	-	0.004	0.024
PERT	-	0.006	0.037
LOB	0.039	0.007	0.001
"S" curves	0.025	0.002	0.048
P.C. Packages	0.026	0.006	0.059

Figure 7: Success = f(Project Value x Control Technique)

	Cost	Schedule	Technical
Informal meetings	-	-	0.001
Formal meetings	-	-	0.008
Reporting	-	-	0.018
Bar / Gantt	-	-	0.026
Milestone	-	-	0.014
PERT	-	-	0.012
LOB	0.022	-	0.003
"S" curves	0.005	-	0.019
P.C. Packages	-	-	0.013

Figure 8: Success = f(Project Duration x Control Technique)

	Cost	Schedule	Technical
Informal meetings	0.000	-	0.031
Formal meetings	0.001	-	0.043
Reporting	0.001	-	-
Bar / Gantt	0.003	-	-
Milestone	0.001	-	-
PERT	0.000	-	-
LOB	0.000	-	0.009
"S" curves	0.000	-	-
P.C. Packages	0.000	-	-

APPENDIX D

CATEGORICAL ANALYSIS

CATEGORICAL ANALYSIS

CONTINGENCY ANALYSIS

The first set of contingency tabulations were performed on the data with the success scales compressed from five factors down to two factors and the Age scale discretised to a 5 factor scale (ie 0-1yrs, 1-3yrs, 3-5yrs, 5-7yrs and >7yrs). The values below being the significance level of the Chi-squared test at 5% or less. An asteriks (*) is used to indicate a warning that the relevant test has an expected frequency of less than 5.

Table 1 : Success = f(Project characteristic)

	Cost	Schedule	Technical
Age	-	0.002	-
Type	-	0.030 *	0.002 *
Value	-	-	0.016 *
Duration	0.002	-	-

Table 2 : Success = f(Technique)

	Cost	Schedule	Technical
Informal meetings	-	-	-
Formal meetings	-	0.042 *	0.059 *
Reporting	-	-	-
Bar / Gantt	-	-	-
Milestone	-	-	-
PERT	-	-	-
LOB	-	-	0.021 *
"S" curves	0.033	-	-
P.C. Packages	-	-	-

Table 3 : Technique = f(Characteristic)

	Age	Type	Value	Duration
Informal meetings	0.050 *	-	-	-
Formal meetings	0.005 *	0.018 *	0.000 *	-
Reporting	-	0.040 *	0.000 *	0.020 *
Bar / Gantt	-	0.006 *	0.000 *	-
Milestone	0.026	0.010 *	0.000 *	0.000
PERT	0.066	-	0.009 *	0.052
LOB	-	-	0.000 *	-
"S" curves	-	0.016 *	0.000 *	0.000 *
P.C. Packages	-	-	0.000 *	0.000 *

Table 4 : Success = f(Responsible Authority)

	Cost	Schedule	Technical
Person	0.004 *	-	0.030 *

Table 5 : Authority = f(Characteristic)

Age	Type	Value	Duration
-	0.001 *	-	0.080 *

In order to attempt eliminating the warnings that the data was insufficient, the second data scale compression was for the project Characteristics. The Age, Value and Duration scales were compressed from 5 factors to three, as follows :

Age	: Initial scale	->	0-1yr; 1-3yr; 3-5yr; 5-7yr; >7yr
	Final scale	->	0-3yr; 3-5yr; >5yr
Value	: Initial scale	->	R0-R10 000; R10 000-R100 000; R100 000-R1million; R1million-R5million ;>5million
	Final scale	->	R0-1million; R1million-R5million; >R5million
Duration	: Initial scale	->	0-6months; 6months-1year; 1-3years; 3-5years; >5years
	Final scale	->	<1year; 1-3years; >3years

The other characteristic scale that was compressed, was that of project type. Here the 6 point scale was compressed to 5 by removing Commissioning Projects.

Table 6 : **Success = f(Characteristic)**

	Cost	Schedule	Technical
Age	0.019	-	-
Type	-	0.044	0.002 *
Value	-	0.08	-
Duration	0.000	-	-

Table 7 : **Technique = f(Characteristic)**

	Age	Type	Value	Duration
Informal meetings	-	-	-	-
Formal meetings	-	0.018 *	0.000 *	-
Reporting	-	0.040 *	0.000 *	0.008
Bar / Gantt	-	0.006 *	0.001	-
Milestone	0.004	0.010 *	0.000	0.000
PERT	0.025	-	0.005	0.007
LOB	0.060 *	-	0.000 *	-
"S" curves	-	0.016 *	0.000	0.000
Computer Package	0.016	-	0.000	0.000

The next scale that was altered was that of Responsible Authority. Previously there was one category with a six point scale. This was altered to six categories, each having a binary scale, the results being :

Table 8 : **Success = f(Responsible Authority)**

	Cost	Schedule	Technical
Project Manager	0.000	-	-
Planning Engineer	0.000	-	0.064
Planning Dept.	-	-	-
Financial Dept.	-	-	-
Admin Dept.	-	-	-
Contractor	-	-	-

LOG-LINEAR MODELLING

The log-linear modeling procedure assumed that the order of the model was 1, and as such produced tables of standard residuals (Percentage observed frequency - Percentage expected frequency) for each of the required models. The functions chosen for modeling were selected from the cross tabulation results, as those functions for which the Chi-squard test indicated a significance level for rejecting the null hypothesis greater than 5%.

Table 13 : Budget Success = f(Duration)

	BUDGET SUCCESS		
	High	Ave	Low
0 - 0,5 yr	+0.7	+0.4	-1.5
0,5 - 1 yr	+0.8	-0.2	-0.7
1 - 3 yr	+0.6	+0.3	-1.2
3 - 5 yr	-1.6	-0.7	+2.9
> 5 yr	-1.7	-0.2	+2.2

The longer projects appear to have a poorer budget success than the shorter ones and the shorter projects appear to have a higher budget success than independence would predict.

Table 14 : Budget Success = f(Age)

	BUDGET SUCCESS		
	High	Ave	Low
0 - 3 yr	+0.8	+0.7	-1.9
3 - 5 yr	-0.5	-1.0	+1.9
> 5 yr	-0.7	-0.1	+1.0

The older projects seem to be more associated with poor budget success than independence would predict.

Table 15 : Budget Success = f("S" curve)

	BUDGET SUCCESS		
	High	Ave	Low
Not used	-0.7	+0.6	+0.1
Occasional use	+0.3	-1.5	+1.7
Extensive use	+1.2	+0.1	-1.6

Budget success appears to be higher the more extensively the "S" curve technique is used, than independence would predict.

Table 16 : Budget Success = f(Project Manager choice)

	BUDGET SUCCESS		
	High	Ave	Low
No	+2.8	-2.0	-0.6
Yes	-1.4	+1.0	+0.3

Budget success appears to be higher when the project manager has little or no influence on the choice of control technique, than independence would predict.

Table 17 : Budget Success = f(Planning Engineer)

	BUDGET SUCCESS		
	High	Ave	Low
No	-1.6	+0.8	+0.8
Yes	+3.0	-1.5	-1.5

Budget success appears to be more improved when a planning engineer had some influence in the choice of control technique, than independence would predict.

Table 18 : Schedule Success = f(Age)

	SCHEDULE SUCCESS		
	High	Ave	Low
0 - 1 yr	-0.4	+1.2	-1.0
1 - 3 yr	+0.4	-1.0	+0.7
3 - 5 yr	-1.2	-0.6	+2.1
5 - 7 yr	-0.7	+2.2	-1.8
> 7 yr	+1.8	-1.2	-0.7

Here there appears to be no apparent trend.

Table 19 : Schedule Success = f(Type)

	SCHEDULE SUCCESS		
	High	Ave	Low
Research	+0.8	+0.3	-1.3
Development	-0.5	+0.2	+0.4
Construction	-1.6	+0.4	+1.4
Implementation	+2.2	-1.5	-0.9
Engineering	0.0	+0.2	-0.3

It would appear that the schedule success of the development and construction projects are poorer than that of research, development and engineering projects, as indicated by the lack of independence.

Table 20 : Schedule Success = f(Value)

	SCHEDULE SUCCESS		
	High	Ave	Low
R0 - R1 million	+0.2	+0.7	-1.1
R1 - R5 million	-1.2	-0.5	+2.0
> R5 million	+0.8	-0.4	-0.5

The smaller and larger projects appear to have higher schedule success while the intermediate size projects (R1 - R5 million) appear to have a lower schedule success than independence would predict.

Table 21 : Schedule Success = f(Milestone)

	SCHEDULE SUCCESS		
	High	Ave	Low
Occasional use	-0.8	+1.2	-0.5
Extensive use	+1.0	-1.5	+0.6

Both high and low schedule success are associated with extensive use of the technique, while selective use (occasional or no use) is more prone to yield an average success than independence would predict.

Table 27 : Formal Meetings = f(Age)

	AGE		
	< 3yr	3-5yr	> 5yr
Occasional use	+1.4	-1.0	-1.0
Extensive use	-1.0	+0.8	+0.8

This suggests that the extensive use of computer based schedule control techniques predict.

Table 28 : Milestone Techniques = f(Duration)

	DURATION				
	0-6mth	0,5-1yr	1-3yr	3-5yr	> 5yr
Not used	+0.3	+2.3	+0.1	-1.8	-2.0
Occasional use	+1.4	-0.5	0.0	-0.2	-0.8
Extensive use	-1.4	-1.8	-0.1	+1.9	+2.5

The extensive use of the milestones on a work breakdown structure approach, appears to be more associated with projects longer than 3 years, than independence would predict.

Table 29 : Network Techniques = f(Duration)

	DURATION				
	0-6mth	0,5-1yr	1-3yr	3-5yr	> 5yr
Not used	+1.4	+1.4	-0.9	-0.8	-1.1
Occasional use	-0.7	-0.2	0.0	+0.3	+0.8
Extensive use	-1.2	-1.8	+1.3	+0.8	+0.6

The extensive use of network procedures appears to be more associated with projects of duration >3 yrs, than independence would predict.

Table 30 : Computer Based Techniques = f(Duration)

	DURATION		
	< 1yr	1-3yr	> 3yr
Not used	+2.0	-0.6	-1.8
Occasional use	-1.5	-0.4	+2.5
Extensive use	-1.8	+1.3	+0.7

The extensive use of computer based schedule control techniques appears more related to longer projects than independence would predict, while on shorter projects they are more infrequently used than independence would predict.

Table 31 : Progress "S" curves = f(Duration)

	DURATION		
	< 1yr	1-3yr	> 3yr
Not used	+1.3	0.0	-1.6
Occasional use	-0.2	-1.5	+2.2
Extensive use	-2.6	+1.3	+1.6

The use of progress "S" curves to control project time appear to be in more extensive use as project duration increases, than independence would predict.

Table 32 : Formal reporting techniques = f(Duration)

	DURATION		
	< 1yr	1-3yr	> 3yr
Not used	+1.0	-0.5	-0.7
Occasional use	+1.7	-0.4	-1.6
Extensive use	-1.8	+0.5	+1.6

This suggests that the relationship between the use of formal reporting techniques and the duration of the project shows a trend of more extensive use of reporting, with increased project duration, than independence would predict.

Table 33 : Bar/Gantt chart = f(Duration)

	DURATION		
	< 1yr	1-3yr	> 3yr
Occasional use	+1.4	-0.6	-1.0
Extensive use	-1.3	+0.6	+0.9

This table suggests that the trend of increasing use of the Bar/Gantt charts with increasing project duration is stronger than independence would predict.

Table 34 : Bar/Gantt Charts = f(Value)

	VALUE		
	< R1mil	R1-R5mil	> R5mil
Not used	+2.2	0.0	-2.4
Occasional use	+1.0	-0.7	-0.5
Extensive use	-2.0	+0.5	+1.8

The extensive use of bar/Gantt charts is more related to high value projects than independence would predict.

Table 35 : Network techniques = f(Value)

	VALUE		
	< R1mil	R1-R5mil	> R5mil
Not used	+2.0	-0.1	-2.3
Occasional use	+0.4	+0.5	-1.0
Extensive use	-2.3	-0.5	+3.0

The infrequent use of network techniques in projects of value less than R1 million, is more pronounced than independence would predict.

Table 36 : Milestone techniques = f(Value)

	VALUE		
	< R1mil	R1-R5mil	> R5mil
Not used	+1.8	-0.1	-1.9
Occasional use	-1.6	+0.8	+1.0
Extensive use	-0.7	-0.9	+1.5

Milestone techniques appear to be in more extensive use as the value of the project increases, than independence would predict.

Table 42 : Reporting = f(Type)

	TYPE OF PROJECT				
	Research	Devel/Des.	Constr.	Implimnt	Engineer
Occasional use Extensive use	+1.1 -1.0	-0.7 +0.6	-0.3 +0.2	+1.9 -1.7	-0.9 +0.8

The suggestion here is that development/design, construction and general engineering projects tend to make more extensive use of formal reporting than independence would predict.

Table 43 : Milestone Technique = f(Type)

	TYPE OF PROJECT				
	Research	Devel/Des.	Constr.	Implimnt	Engineer
Occasional use Extensive use	-0.1 +0.2	-0.9 +1.1	+1.4 -1.7	+1.1 -1.3	-1.1 +1.4

This suggests that milestone techniques are more extensively (than occasionally) used on research, development/design and general engineering projects, than independence would predict.

Table 44 : Bar/Gantt chart = f(Type)

	TYPE OF PROJECT				
	Research	Devel/Des.	Constr.	Implimnt	Engineer
Occasional use Extensive use	+2.4 -2.1	+0.8 -0.7	-1.1 +0.9	-0.1 +0.1	-0.6 +0.5

Here it appears that extensive use of Bar/Gantt charts are more associated with construction, implementation and general engineering projects, than independence would predict.

APPENDIX E

INDUSTRIAL SURVEY LIMITATIONS

SURVEY LIMITATIONS

The limitations have been divided into three parts, namely considerations pertaining to the survey procedure, to the questionnaire and its construction, and to the analysis performed on the resulting responses. These limitations have been fully detailed below.

a. **Survey Procedure:**

- The survey was limited to industrial/engineering projects in the South Western Cape. How representative this is of projects in general, or even of industrial/engineering projects elsewhere, is a debateable issue.

- The survey conducted was a mailed questionnaire. In such a survey, the researcher is limited by the number of questions he can ask. This is an inflexible approach and does not allow detailed examination of organisational practices. At the very least this approach should have some of the results qualified with follow-up interviews.

- Mailed surveys have notoriously poor returns.

- With this type of survey, the researcher can never be sure of how representative of the targeted research, his results in fact are. It is further impossible to fully establish how representative the response is of a specific organisation, or whether the respondent has been prejudiced in his choice of projects to report (ie. only the better or more pristine projects reported), without follow-up interviews.

- A further grey area with a mailed survey, is whether the results obtained have been self-biased, in that a specific type of project manager may be the type to return mailed surveys. Hence the returns themselves would be biased before the results have even been considered.

b. **Questionnaire Construction:**

- The questionnaire constructed included survey questions from a second researcher, whose topic considered some overlapping issues, but whose emphasis was on project appraisal and not time/schedule control. It is a real fear that although resources were conserved with such an approach, that respondents may well have had knowledge of the one topic and not really the other.

- The use of this combined survey made the questionnaire fairly long. This could have made its completion tedious, so promoting errors. Added to this was the fact that each respondent was asked to answer on anything up to five projects. It is thus conceivable that the responses to questions, on individual projects, may well have been duplicated by the respondent out of frustration.

- Although the scaling factors used in the questionnaire were aimed at providing as much information per question as possible, without being confusing, one cannot say whether the respondents found them confusing or contradictory.

- The responses required of the respondents, sometimes meant that the questions themselves were open to a degree of interpretation. Examples being; question 3. on the classification of "type of project", and question 5. concerning the "types of technique". Further, the question regarding the perceived success of the project (question 15.), is open to not only bias, but also subjectivity and dishonesty.

- It was decided not to include the characteristic variable "complexity" in the survey, as it was felt that this was a particularly subjective characteristic. It was decided that it could be adequately ascertained from such variables as duration and value.

c. **Data Analysis**

- The statistical data analysis. Assumes that the frequency distributions of the data are approximately normal. In most instances there is evidence to suggest this assumption is reasonable, but not in all cases.

- Various procedures were used in the analysis, the limitations of these procedures should also be mentioned. Although these limitations have been explained in some detail in section 3, examples include: The inability of the graphics to portray multi-relationships. The fact that all techniques, with the exception of contingency analysis, provide no indication of the statistical adequacy of the data. Further, the ANOVA techniques are strictly applicable in the case where the predictor variables are continuous, however, the data from the survey was mostly discreet.

- In order to statistically test for the presence of multi-relationships, using categorical analysis, the contingency tables become three dimensional. In such cases, the amount of research data required in order to obtain meaningful results multiplies. For this reason, it is possible that the size of the survey response was insufficient to prove such relationships with a significant degree of certainty.